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Prepared by participants in the 1968 National Defense Education Act Institute on Wood Technology, this syllabus is one of a series of basic outlines designed to aid college level industrial arts instructors in improving and broadening the scope and content of their programs. This booklet is concerned largely with the physical composition and behavior of wood and the factors influencing its utilization. Headings of the five major units are: (1) Wood, What It Is, (2) The Plant Origin of Wood, (3) Gross Features of Wood, (4) Natural Defects in Wood, and (5) The Identification of Wood. A section of experiments, including teaching aids, equipment needed, sample test questions, suggested student problems and projects, and references, presents information on such properties of wood as density and specific gravity, moisture content, strength characteristics, and structure. The guide is illustrated throughout with drawings, diagrams, photographs, tables, and graphs. A glossary and bibliography are included. Related documents are available as VT 007 857, VT 007 858, and VT 007 859. (AW)

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WOOD PROPERTIES & KINDS

A
BASE SYLLABUS
ON
WOOD TECHNOLOGY

Prepared by
INSTITUTE PARTICIPANTS

EASTERN KENTUCKY UNIVERSITY
UNITED WE STAND ★ DIVIDED WE FALL
FOUNDED 1906
RICHMOND

N.D.E.A. INSTITUTE
for advanced study in
INDUSTRIAL ARTS
June 10 - August 2, 1968

VT007861

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in the

Wood Technology

N.D.E.A. Institute

EASTERN KENTUCKY UNIVERSITY

June 10-August 2, 1968

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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PREFACE

Recently, the area of woodworking has come under much criticism as being too limited in scope and not fully abreast of an advancing technology. Some people have gone as far as to seek its abolition from the industrial arts program in the secondary schools. In reality, however, the importance of woodworking as a phase of industrial arts is probably greater now than ever before. It is conceded, nevertheless, that the scope and content of industrial arts woodworking programs needs to be improved.

Traditionally, a typical woods program is centered upon the use of hand and machine tools with little or no emphasis given to the problem of familiarizing students with technical knowledge of the material itself.

To assist in the upgrading of present programs, students and teachers should, in addition to the use of wood as lumber, be made aware of the various properties of wood and wood products. Of equal importance is a knowledge of new processes and materials used in conjunction with the fabrication, manufacture, and application of wood and wood-related products.

The purpose of the NDEA Institute in Wood Technology held at Eastern Kentucky University during the period June 10 - August 2, 1968, was to provide college level industrial arts woodworking instructors with the opportunity to receive information in depth which they might use to broaden the scope and content of their programs. To this end, the participants have prepared this series of Basic Outlines which attempt to record their experiences during the period of the institute. The "Base Syllabus" prepared by the participants in the 1967 Wood Technology institute was used as a guide in developing the format of this series.

It is hoped that the material covered herein will be applied to the improvement of each participant's woodworking program and lead their students to a greater understanding of wood and wood products.

Jack A. Luy

Institute Director

WOOD PROPERTIES AND KINDS

Introduction

"We may use wood with intelligence only if we understand wood." Frank Lloyd Wright

Wood is a material which has been used extensively in manufacturing, construction, transportation, and the service industries. Wood and its many by-products continue to gain prominence in our industrial society as a result of the many technological advances and recent concepts related to its utilization. There is seemingly no end to the possibilities for varied uses of ingredients found in wood.

For this reason, it is necessary for we as Industrial Arts teachers to make a comprehensive study of wood, of its composition, its physical behavior, and the causes of variability as they affect its utilization.

Contained within this booklet are outlines related to the density and specific gravity of wood, moisture content, strength characteristics, seasoning of lumber, the structure of wood, and a glossary of terms used in woodworking technology.

It is hoped that this booklet will be of value to assist in the upgrading of present Wood Technology and Industrial Arts programs and lead their students to a greater understanding of wood.

UNIT I

WOOD, WHAT IT IS

I. Wood is not a solid, homogeneous substance, but a porous one composed of large numbers of very small elements or cells.

  A. There are many parts of a tree evidenced in its cross section that play a part in its life history. (Figure I)

    1. The cambium layer is the one-cell thick layer of tissue between the bark and wood.

      a) The cambium repeatedly subdivides to form new wood and bark cells.

    2. The inner bark or phloem which is the living part of the bark, carries prepared food from the leaves to all growing parts of the tree.

    3. The outer bark or corky layer is composed of dry dead tissue and gives general protection against external injuries.

    4. The sapwood or xylem is the light-colored wood beneath the bark.

      a) The sapwood contains living cells and has an active part in the life process of the tree.

      b) It is located next to the cambium and functions in sap conduction and storage of food.

      c) The sapwood layer may vary in thickness from 1 1/2 to 2 inches in radial thickness.

    5. The heartwood or xylem is the dark inactive wood that is formed by a gradual change in the sapwood. The heartwood gives the tree strength.

    6. The pith is the soft tissue about which the first wood growth takes place in the newly formed twigs. The pith is probably functionless.

    7. The wood rays connect the various layers from pith to bark. The rays store and transfer food.

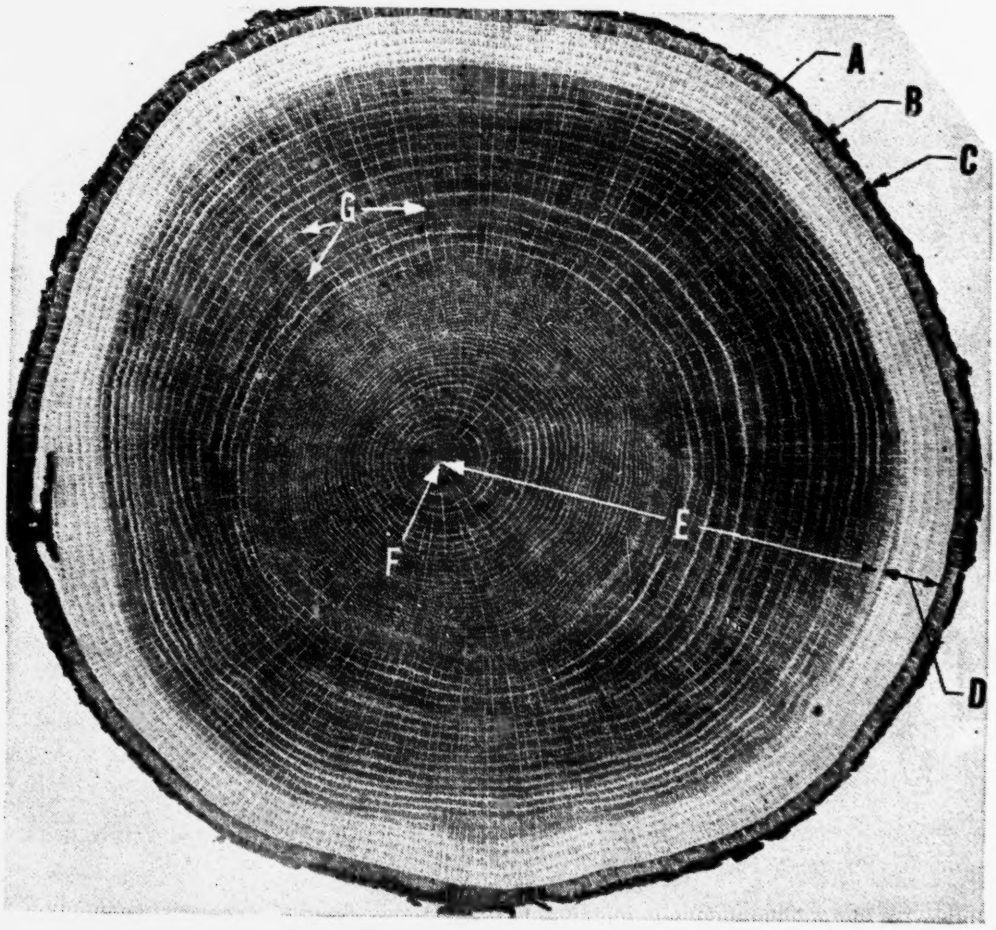

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Figure 1.—The tree trunk: *A*, Cambium layer (microscopic) is inside of inner bark and forms wood and bark cells. *B*, Inner bark is moist and soft. Carries prepared food from leaves to all growing parts of tree. *C*, Outer bark or corky layer is composed of dry dead tissue. Gives general protection against external injuries. *D*, Sapwood is the light-colored wood beneath the bark. Carries sap from roots to leaves. *E*, Heartwood (inactive) is formed by a gradual change in the sapwood. Gives the tree strength. *F*, Pith is the soft tissue about which the first wood growth takes place in the newly formed twigs. *G*, Wood rays connect the various layers from pith to bark for storage and transference of food.

B. There is sufficient difference between the wood formed early and that formed late in a growing season to produce well marked annual rings.

1. The inner part of the growth ring formed first in the growing season is called springwood or earlywood, and the outer part formed later in the growing season, summerwood or latewood.

2. Springwood is characterized by cells having relative large cavities and thin walls.

3. Summerwood cells have smaller cavities and thicker walls.

4. Springwood is lighter in weight, softer and weaker than summerwood.

II. Native species of trees are divided into two classes--deciduous or hardwoods, which have broad leaves and shed them at the end of the growing season, and coniferous or softwood, which have needlelike leaves as pines.

A. The structure of softwoods.

1. The softwoods are simpler in structure than hardwoods.

2. Softwoods are generally considered to be non-porous woods.

3. The greater part of softwood consist of tracheids, which are both water conducting and supporting elements. The tracheids are very long (one-eight to one-third inch). cells that constitute the greater part of the structure of the structure of the softwoods.

4. The pit is the portion of the cell wall where a thin membrane may permit liquids to pass from one cell to another.

5. The rays are strips of cells extending radially within a tree. The rays serve primarily to store food and transport it horizontally in the tree.

6. The resin ducts are intercellular passages that contain and transmit resinous materials. They may extend vertically parallel to the axis of the tree or at right angles to the axis.

B. The structure of hardwoods. (Figure 2)

1. Fibers are long (one twenty-fifth or less to one-third inch) narrow, tapering wood cells closed at both ends. They are mechanical elements, concerned with support and are called libriform fibers.

2. The parenchyma cells are used for storage of food and waste materials and for passing on food and water to other parts of the wood. They also have a supporting function.

3. Vessels and trecheids are conducting elements, the purpose of which is to convey water and dissolved mineral salts from the roots to the leaves.

4. The lumina is the small openings of the cells.

5. The lamella is the thin elastic middle wall that seperates two vessels that come in contact with each other.

6. Tyloses is the pit membrane that is forced into the cavity of the vessel and the vessel becomes blocked with these numerous ingrowths.

7. The rays are sheets of cells that run through the wood in a radial direction.

   a) They usually consist of parenchyma cells and vary in size and shape.

   b) Sheets of cells no more than one cell wide is called uniseriate rays.

III. The four major chemical components of woods are extractives, ash forming minerals, lignin, and cellulose. (Figure 3)

A. The extractivies are not part of the wood structure but contribute to the wood such properties as color, taste, odor, and resistance to decay.

1. They include tannins, starch, coloring matter, oils, resins, fats, and waxes.

2. They can be removed by natural solvents.

B. Ash forming minerals, lignin, and cellulose make up the wood structure.

1. Cellulose is the carbohydrate that is the principal constituent of wood and forms the frame work of the wood cell.

   a) Cellulose comprises about 70 per cent of the wood.

   b) It is subdivided into alpha-cellulose and hemicellulose.

THE CHEMICAL COMPOSITION OF WOOD

Patterned after B.L. Browning, Methods of Wood Chemistry
Interscience Publishers, New York City

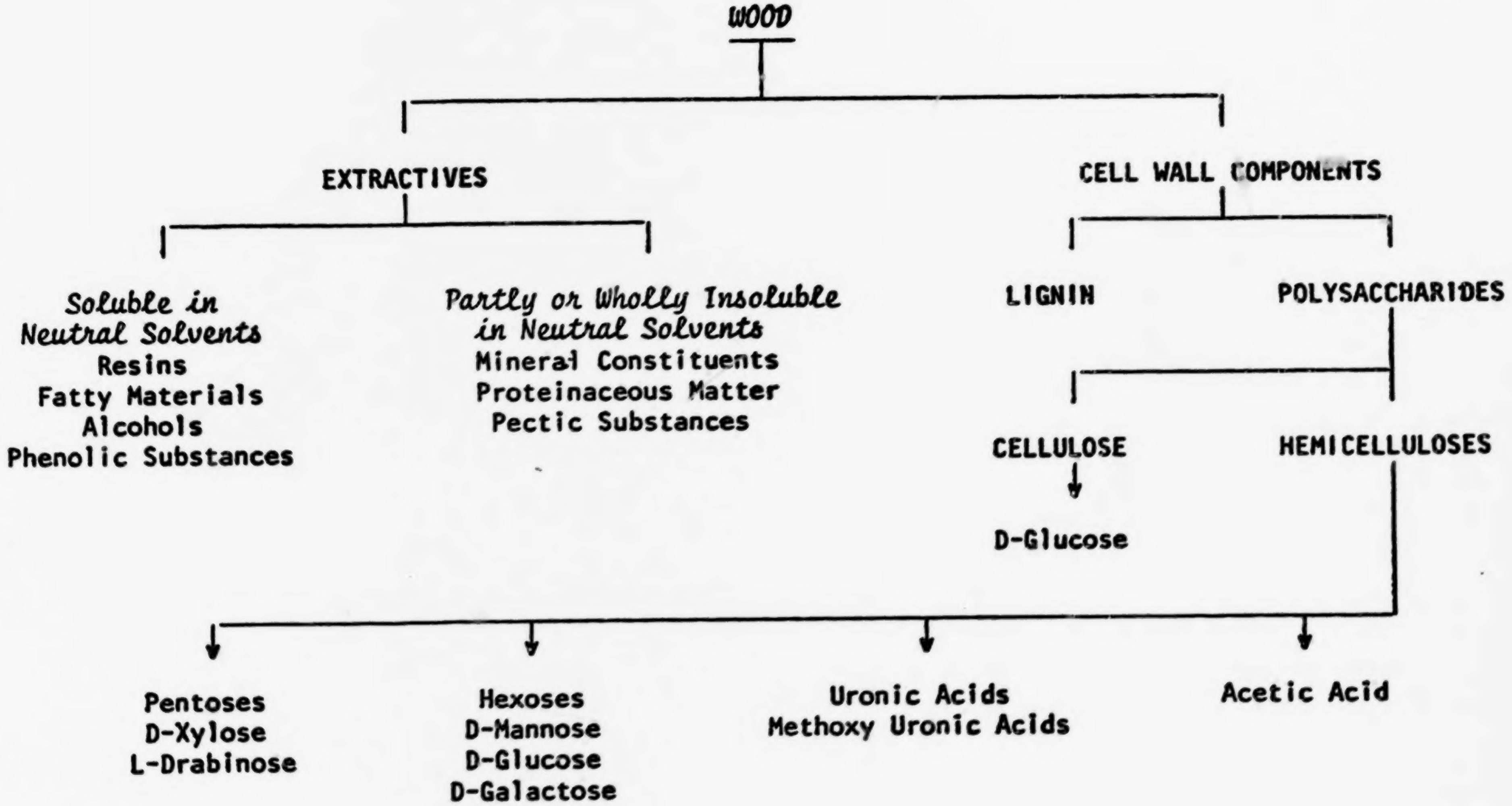
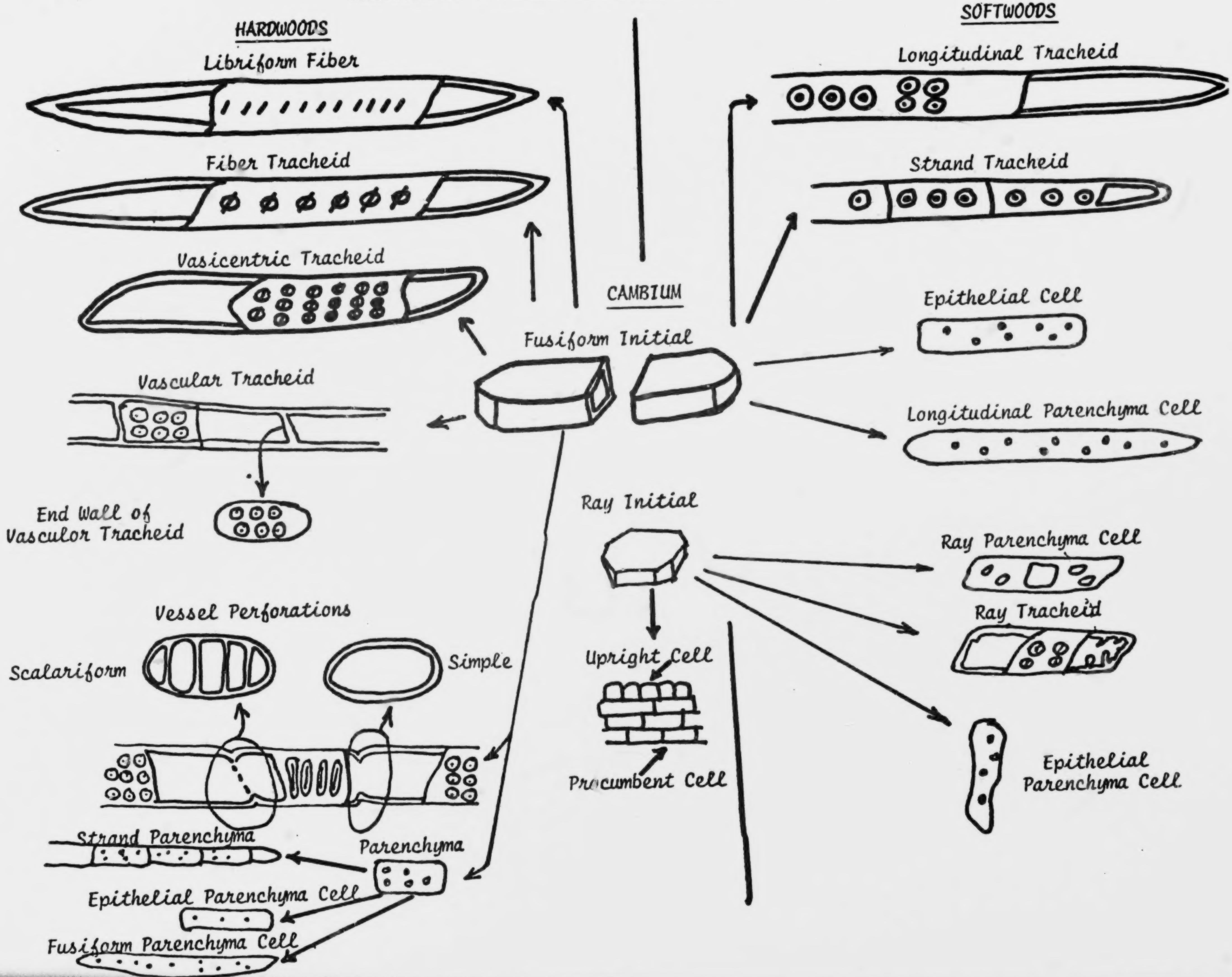

WOOD
EXTRACTIVES
CELL WALL COMPONENTS
Soluble in Neutral Solvents
Resins
Fatty Materials
Alcohols
Phenolic Substances
Partly or Wholly Insoluble in Neutral Solvents
Mineral Constituents
Proteinaceous Matter
Pectic Substances
LIGNIN
POLYSACCHARIDES
CELLULOSE
D-Glucose
HEMICELLULOSES
Pentoses
D-Xylose
L-Drabinose
Hexoses
D-Mannose
D-Glucose
D-Galactose
Uronic Acids
Methoxy Uronic Acids
Acetic Acid

Figure 3

ELEMENTS OF SECONDARY WOOD AND CAMBIAL INITIALS


HARDWOODS
Libriform Fiber
Fiber Tracheid
Vasicentric Tracheid
Vascular Tracheid
End Wall of Vasculor Tracheid
Vessel Perforations
Scalariform
Simple
Strand Parenchyma
Parenchyma
Epithelial Parenchyma Cell
Fusiform Parenchyma Cell
CAMBIUM
Fusiform Initial
Ray Initial
Upright Cell
Procumbent Cell
SOFTWOODS
Longitudinal Tracheid
Strand Tracheid
Epithelial Cell
Longitudinal Parenchyma Cell
Ray Parenchyma Cell
Ray Tracheid
Epithelial Parenchyma Cell

        c) These are the main basis of useful products such as paper, explosives, synthetic textiles, and plastics.

    2. Lignin cements the structural units of wood togehter and thus imparts rigidity to the wood. It comprises 18 to 28 percent of the wood.

    3. The ash forming minerals are the nutrient plant-food elements of the tree. Then comprise from .2 to 1 percent of the wood.

C. There are many outstanding characteristics of wood that show variation in figures caused by growth. Figure is the ornamental markings on the surface of wood produced by the relative arrangement of the different elements in the wood, and can be produced in a number of ways.

    1. The grain of the wood produces most figures by direction of the fibers, as in a straight grain, spiral grain and curly grain.

    2. Plain sawing, quarter sawing, and rotary sawing the wood produced figures in wood.

    3. Stump or butt woods are highly figured. They are produced when large roots join the trunk.

    4. The crotch figure is produced when large branches join the trunk.

    5. Burls are large wart-like excrescences on tree trunks formed by an injury.

    6. Birds-eye is due to local sharp depressions in the annual rings.

IV. Woods should be selected according to the requirements of the articles produced.

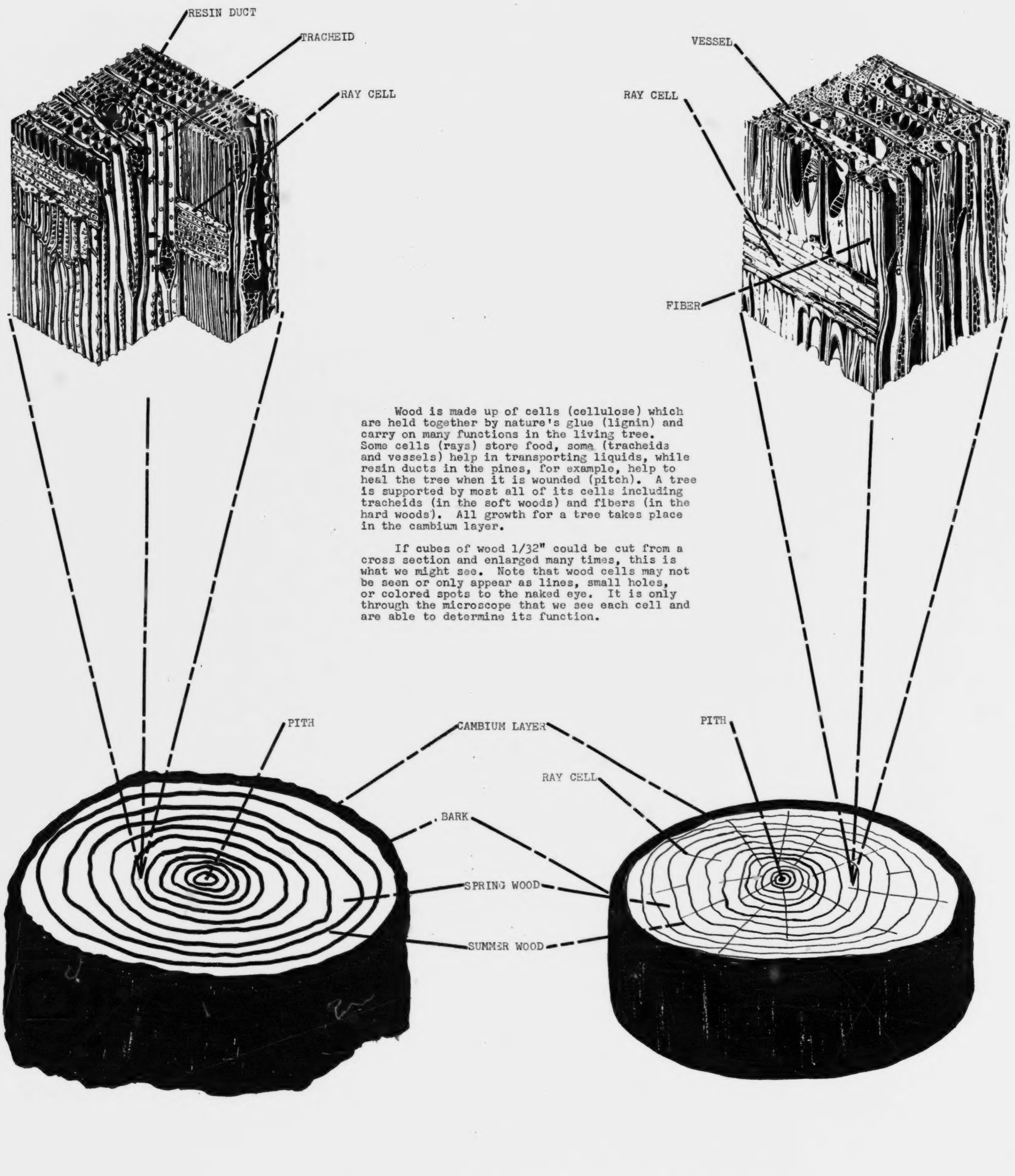
A. Good appearance is required in wood used for most kinds of woodworking.

B. Wood should be seasoned to about the average moisture content that it will have in service.

C. Wood should be sufficiently tough and strong enough to resist denting in ordinary usuage.

D. Appearance, style, and finishing qualities are the properties dominating the selection of woods for furniture.

THE CELL STRUCTURE OF WOOD


RESIN DUCT
TRACHEID
RAY CELL
VESSEL
RAY CELL
FIBER
PITH
CAMBIUM LAYER
PITH
RAY CELL
BARK
SPRING WOOD
SUMMER WOOD

Wood is made up of cells (cellulose) which are held together by nature's glue (lignin) and carry on many functions in the living tree. Some cells (rays) store food, some (tracheids and vessels) help in transporting liquids, while resin ducts in the pines, for example, help to heal the tree when it is wounded (pitch). A tree is supported by most all of its cells including tracheids (in the soft woods) and fibers (in the hard woods). All growth for a tree takes place in the cambium layer.

If cubes of wood 1/32" could be cut from a cross section and enlarged many times, this is what we might see. Note that wood cells may not be seen or only appear as lines, small holes, or colored spots to the naked eye. It is only through the microscope that we see each cell and are able to determine its function.

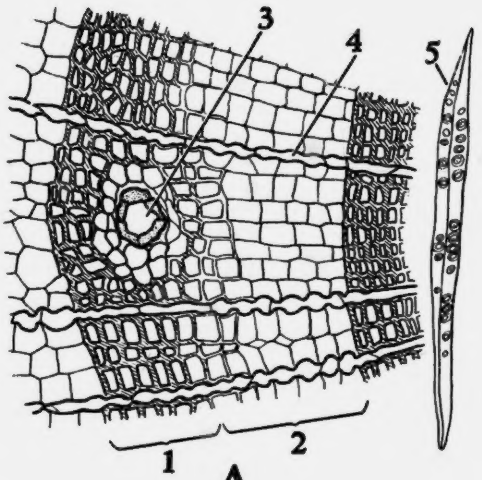
SOFTWOOD - PINE

HARDWOOD - GUM

R.M. Bartlett

TURTOX QUIZ SHEET
for
Anatomy of Wood

Student________________________________



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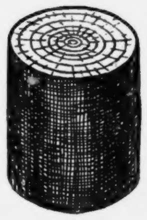

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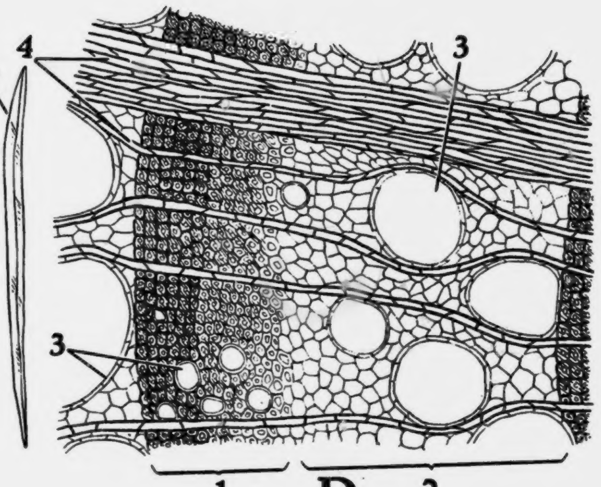

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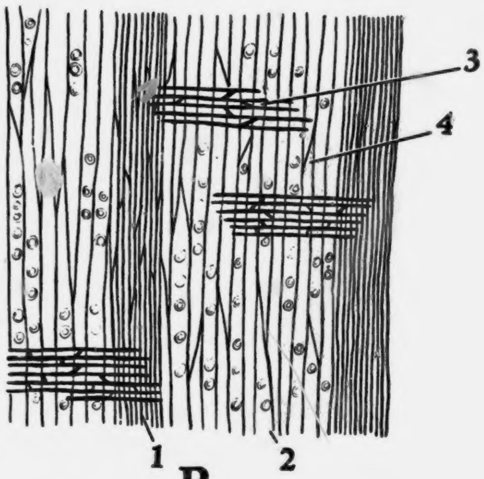

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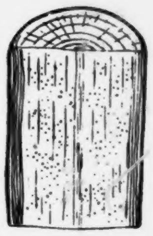

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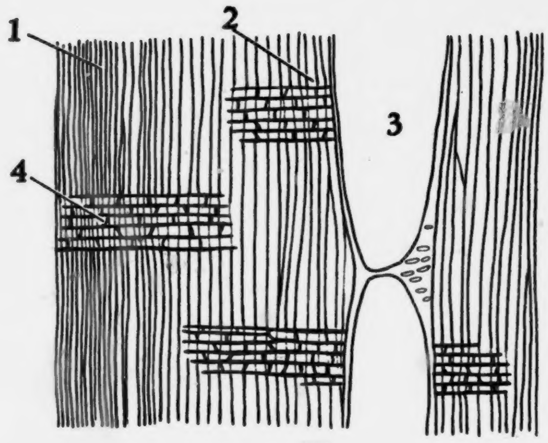

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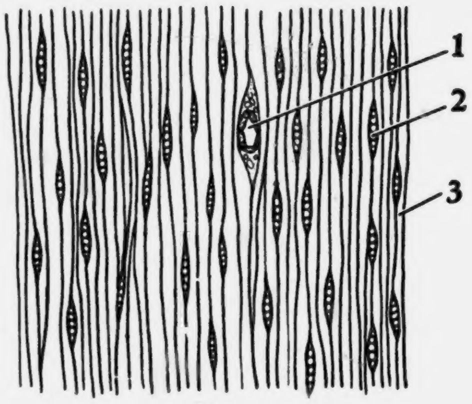

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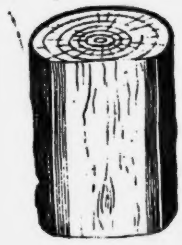

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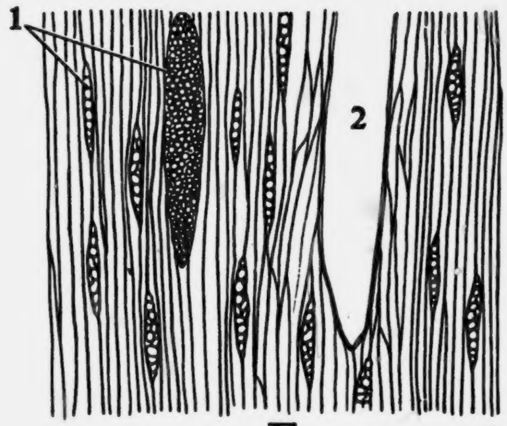

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H.E.Story

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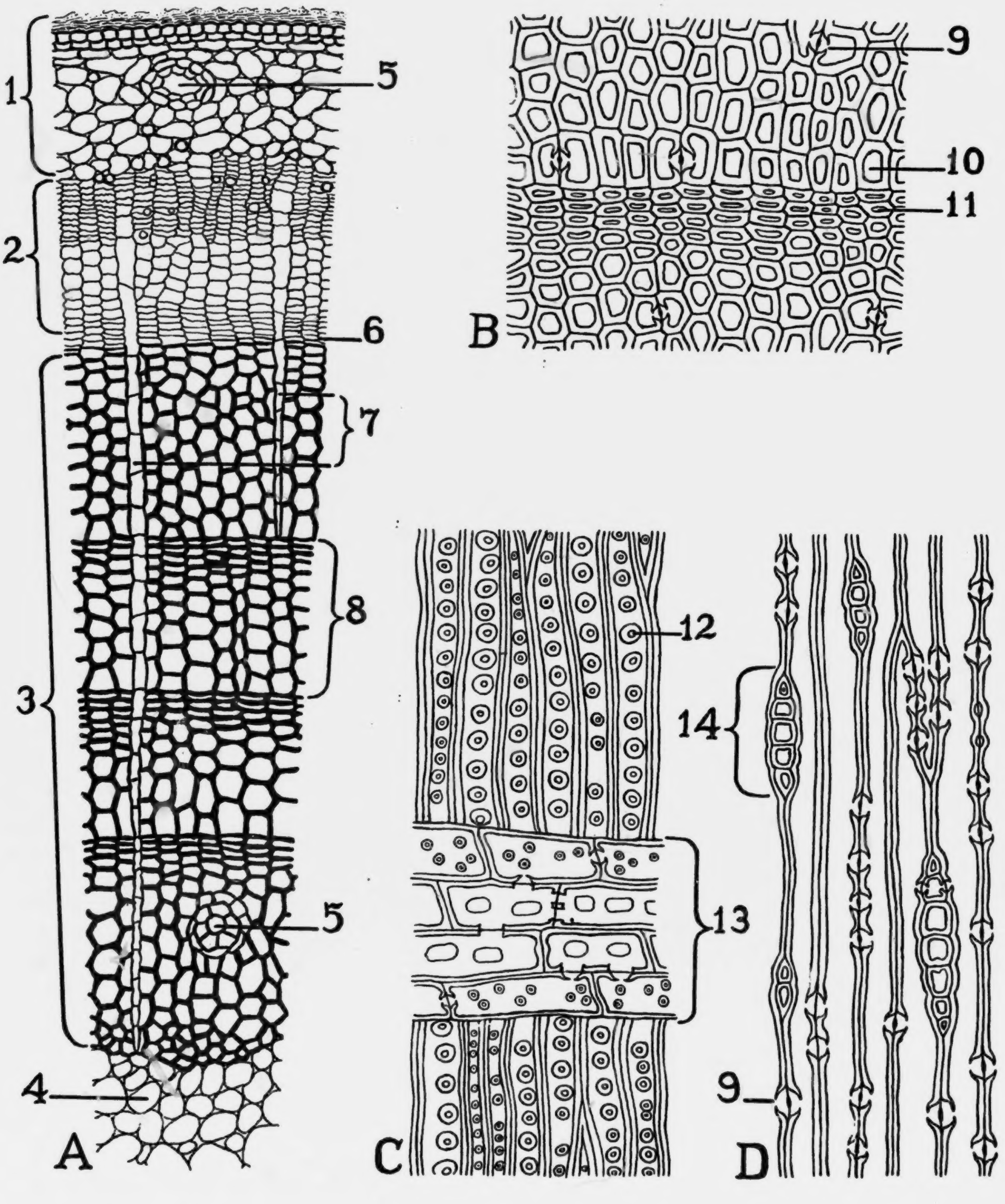
TURTOX QUIZ SHEET
for
Pine Stem

Student____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ANATOMY OF WOOD

Answer Sheet for Turtox Plates

White Pine

Figure A.

1. Summerwood Cells
2. Springwood Cells
3. Resin Duct
4. Ray
5. Tracheids

Figure B

1. Summerwood
2. Springwood
3. Ray
4. Tracheids

Figure C

1. Resin Ducts
2. Ray
3. Tracheid

Tilia (Basswoof) Stem

1. Cortex
2. Phloem
3. Xylem
4. Cork
5. Cork Cambium
6. Fiber
7. Sieve Tube
8. Cambium
9. Ray
10. Vessel or Pore
11. Summerwood
12. Springwood
13. Annual Ring
14. Pith

Red Oak

Figure D

1. Summerwood Cells
2. Springwood Cells
3. Springwood Vessel
4. Large & Small Rays
5. Fiber

Figure E

1. Summerwood
2. Springwood
3. Vessel
4. Rays

Figure F

1. Ray
2. Vessel

Pine Stem

Figure A

1. Cortex
2. Phloem
3. Xylem
4. Pith
5. Resin Duct
6. Cambium
7. Rays
8. Annual Ring

Figure B

9. Border Pit
10. Springwood
11. Summerwood

Figure C

12. Border Pit
13. Long Ray
14. Rays

CALIFORNIA STATE COLLEGE
LONG BEACH

WOOD TECHNOLOGY

CELL STRUCTURE AND ARRANGEMENT

Purpose: To investigate the cellular growth patterns and arrangements in wood in order to gain a better understanding of its structural properties and general make-up.

Apparatus required:

Microscope
4 - microscope slides and cover plates
Binding tape
Block plane
Green tree stem
Hydrochloric acid
Phloroglucinol
Botany pen and black ink
Drawing paper
Colored pencils and pens

Experiment:

1. Obtain a tissue thin horizontal and vertical section of the tree stem. If possible, each specimen should include cellular material from the outer bark to the pith.

2. Place the specimens on a clean sheet of glass and apply one or two drops of phloroglucinol to them. Wait five minutes and then put the same amount of hydrochloric acid on the samples. Wait another five minutes and carefully wash the acid from the wood. DO NOT ALLOW THE ACID TO COME IN CONTACT WITH YOUR SKIN OR EYES.

3. After the samples have completely dried, mount them on the microscope slides. An identification label must be placed on this slide with the following information:

   Type of wood
   Type of section (cross or vertical)
   Area covered (pith or cortex)
   Your name and date

   Place this label on the left end of your slide.

4. Study the sections and note the variations in cell shape and arrangement from one major portion of the stem to another. Make a drawing of the cellular structure and identify the following parts with arrow leaders and labels:

Pith	Heartwood
Cambium	Sapwood
Bast or Phloem	Cortex
Summer growth ring	Spring growth ring

   You may refer to a botany book for varification of your findings before putting your drawings into their final state.

5. Draw a vertical-section and cross-section of a tree stem and label the above mentioned parts with arrowed leaders. Recopy your sketches of the above mentioned parts and locate them on this same page alongside the appropriate label and leader arrow. The major sections (cross and vertical) are to be at least 4 inches in size and centered on to a page. The microscopic studies illustrated placed in circles around the section drawings. All work must be in color.

6. On a single sheet, draw and label the following cells 3" in size, in color:

   Vessel
   Fibre
   Trachied

Questions:

1. What is a vascular bundle?
2. In which direction is the cell arrangement predominantly aligned?
3. What is the function of the pith?
4. What is the function of the heartwood?
5. What is the function of the sapwood?
6. What is the function of the cambium?
7. What is the function of the bast or phloem?
8. What is the function of the cortex?
9. How are the new cells formed?
10. Why is it that only heartwood and sapwood is used as a structural material with the exclusion of the pith, bast and cortex?
11. What is an annual growth ring?
12. What is meant by a "false ring"?
13. What types of cells are found in hardwoods?
14. What types of cells are found in softwoods?
15. What is meant by the terms "conductive tissue" and "supportive and conductive tissue"?

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UNIT II

THE PLANT ORIGIN OF WOOD

I. Types of Plants Producing Wood
Wood is of plant (vegetable) origin.

A. Characteristics of Woody Plants

1. Woody plants must be vascular plants, i.e., possess specialized conducting tissues consisting of xylem (wood), and pholem (inner bark).

2. Must be perennial plants, i.e., live for a number of years.

3. Must possess a stem that persists from year to year.

4. Must exhibit secondary thickening, i.e., this is achieved through a growing layer, called cambium.

B. Types of Woody Plants

1. Tree - A woody plant that attains a height of at least 20 feet containing usually a single self-supporting stem or trunk.

2. Shrub - A woody plant that seldom exceeds a height of 20 feet containing usually a number of stems.

3. Woody Liana - A climbing woody vine.

II. Classification of Vegetable Plants
There are four main divisions in the vegetable kingdom.

A. Thallophytes - as represented by algae (pond scums, seaweeds), fungi (mushrooms, bracket fungi), and bacteria. They constitute the lowest division of the vegetable kingdom. Sexually absent in many forms.

B. Bryophytes - as represented by liverworts and mosses. Sexuality definitely established.

C. Pteridophytes as represented by ferns, scouring rushes, horsetails, club mosses, and quillworts. Sex type may be distinguished. True roots, stems and leaves equipped with special conducting or vascular tissue are present. Stems are too small and short-lived for conversion into lumber.

D. Spermatophytes - constitute all seed plants. They represent the highest type to date, possessing true roots, stems and leaves. Spermatophytes are divided into two subdivisions.

1. Gymnosperms - Greek for naked seeds. Seeds not enclosed in any ovary. Gymnosperms are very ancient. Some 650 forms exist today. Four living orders are recognized.

   a) Cycacales - 9 genera - about 8 species. Woody plants of the tropics as represented by tree ferns and palms. Structure of the stem does not permit conversion into lumber.

   b) Ginkgoales - 1 species - A deciduous tree with the habit of a conifer. Wood is suitable for commercial use but growing range (China - Japan) limited.

   c) Gentales - 3 genera - Some 60 odd species. Probably the most recent order of gymnosperms. The Gentales are not a source of wood.

   d) Coniferales - 46 genera - Some 500 species are recognized. They alone among Gemnosperms are productive of timber on a commercial scale. They are known as conifers, evergreens, or softwoods. Its relatively small botanical size is all out of proportion to its economic importance. This is because of the following reasons:

      (1) Coniferous trees grow in almost pure wide stands which make harvesting economically feasible.

      (2) Exist in temperate zones where the demand is greatest.

      (3) Exhibit monopodial growth which manifests itself in greatest lumber yield.

      (4) The wood is of a type that lends itself to many uses.

2. Angiosperms have evolved recently in a geological sense. (Lower Cretaceous). Are represented by at least 150,000 species. The most obvious characteristics that set off this group are the presence of a flower, with its showy pereanth, stamens, and pistol and the manner in which the ovules are borne enclosed in an ovary. There are two classes of Angiosperms.

   a) Monocotyledons - One seed leaf (cotyledon). Vascular bundles within the stem are scattered. Include 30,000 species, 7 orders, embracing 48 families.

   b) Dicotyledons - Include 120,000 species, 30 orders, some of which are represented wholly by herbaceous forms; others wholly of woody plants - still others contain both woody and herbaceous species. Dicotyledons are the source of the hardwood lumber trade. They possess greater diversification in wood structure than in gymnosperms.

III Factors controlling the designation of a wood as commercially important. Of the 1,027 different trees growing in the United States, 80 are commercially important. Thirty softwoods and 50 hardwoods.

A. Six factors must be considered before selecting a timber for commercial use.

1. Growth - A timber must be of adequate size to make it profitable for harvesting. However, smaller trees, such as aspen, are used in great quantities by the paper-making industry.

2. Quality - Trees that may have the necessary size are often ruled out because the wood is not of sufficient value under the prevailing economic conditions.

3. Accessibility - This factor is only slightly important in the United States compared to the potentially valuable timbers contained in other less technically developed countries.

4. Quantity - An adequate supply must be available at a price not prohibitive to the consumer.

5. Transportation and Industry - Transportation facilities must be adequate and within a reasonable distance to the harvesting site, processing plants and consumer.

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UNIT III

GROSS FEATURES OF WOOD

The features of wood which can be detected by sight, taste, or odor are termed gross features. They aid in species identification, which is necessary for further understanding of specific characteristics of a particular wood within a given species.

I. Growth Rings

A ring of wood cells clearly seen on a transverse section which resulted from periodic growth. One growth ring per year is typical and is known as an annual ring.

A. Location

1. Located between the bark and the wood is a layer of thin-walled living cells called the cambium, in which all growth in thickness of bark and wood arises - by cell division. New wood cells are formed on the inside of this layer.

2. In temperate climates many species show a marked difference between wood formed early and that formed late in a growing season.

B. Characteristics

1. The approximate age of a tree may be determined by counting the growth rings.

2. The first five or six years of growth may be impossible to count.

3. Severe drought or defoliation may cause more than one growth ring within one season.

4. The width of rings and number per inch is a measure of rate of tree growth.

II. Sapwood - (Xylem)

The living portion (cells) of a tree trunk is called sapwood. Every part of wood in every tree has at one time been sapwood.

A. Location

1. It is located next to the cambium (toward the center of the tree)

B. Function

1. Give support to the tree

2. Conduct sap

3. Store reserve food

C. Characteristics

1. The sapwood layer may vary in thickness and in the number of growth rings contained in it.
2. Commonly ranges from 1 1/2 to 2 inches in radial thickness.
3. Sapwood is widest in the upper trunk toward the crown and decreases in width toward the base.
4. Usually lighter in color than heartwood.
5. Less dense than heartwood and usually lighter in weight in the green state.
6. Rich in plant food material which makes it attractive to certain wood-rotting fungi and insects.

III. Heartwood (Xylem)

Heartwood consists of inactive cells formed by changes in the living cells of the inner sapwood rings presumably after their use for sap conduction and other life processes of the tree have largely ceased.

A. Location

1. The major central portion of the tree trunk.

B. Function

1. Give support to the tree.

C. Characteristics

1. Usually darker in color than sapwood due to deposits of certain materials (extractives) within the pores.
2. Heartwood tends to be heavier than sapwood due to the presence of these extractives.
3. Heartwood is denser and therefore heavier than sapwood.
4. Heartwood has higher compressive and shear strength than sapwood.
5. Heartwood is harder than sapwood.
6. Heartwood is generally resistant to fungal growth and insect attack.
7. Heartwood cells are less permeable than sapwood cells.

IV. Compression Wood

An abnormal type of wood that is characteristic of softwood trees in which the pith is off center as might occur in leaning trees.

A. Characteristics

1. May occur in all softwood (coniferous) species.

2. It is denser and harder than normal wood.

3. Has wide annual growth rings that are usually eccentric.

4. Has what appears to be exceptionally large proportion of summer wood growth.

5. Color contrast between springwood and summerwood is usually less than in normal wood.

6. Has larger shrinkage along the grain than normal wood and low strength for its weight.

7. Warps easily in the rough and particularly when milled.

V. Tension Wood

An abnormal type of wood that occurs in many hardwood species, mainly on the upper side of leaning trees.

A. Characteristics

1. Lumber containing a moderate to large number of abnormal fibers will warp excessively and readily shrink longitudinally.

2. These abnormal fibers hold together tenaciously and project from sawn surfaces.

3. These fibers tend to tear when being planed or cause raised grain.

VI. Grain

Grain is often used in reference to the annual rings, as in fine grain and course grain. It is also used to indicate the direction of the fibers, as in straight grain, spiral grain, and curly grain.

A. Characteristics

1. Technically grain is the direction of the fibers relative to the axis of the tree or the longitudinal edges of individual pieces of timber.

B. Types of Grain

1. Straight grain - Grain which is straight and regular.

2. Irregular Grain - The wood fibers are at varying and irregular inclinations to the vertical axis in the log.

3. Diagonal Grain - A milling defect which results from otherwise straight-grained timber being cut so that the fibers do not run parallel with the axis of the board or plank.

4. Spiral-grain - Result when fibers take a spiral course about the trunk of a tree, instead of the normal vertical course.

5. Interlocked grain - Produced when fibers of successive growth layers being inclined in opposite directions.

6. Wavy grain - Wood in which the fiber collectively take the form of waves or undulations.

VII. Texture

Texture applies to the relative size and amount of variation in size of the cells.

A. Types of Texture

1. Fine texture - Elements are small and close.

2. Course - Elements are large and wide apart.

3. Even - Implies that there is a comparative absence of variation in the elements and little difference between spring wood and summer wood.

4. Uneven - When there is strong variation in the element, it is termed uneven texture.

VIII. Figure

Figure is the pattern produced in a wood surface by annual growth rings, rays, knots, deviations from regular grain, and irregular coloration.

A. Kinds of Figure

1. Curly or wavy - This figure results from waves in the grain direction approximately at right angles to the longitudinal axis of the board. Variable light reflection produces the curly appearance on flat surfaces.

2. Broken strip - A combination of interlocked and wavy grain resulting in a ribbon figure which does not extend the full length of the piece.

3. Blister and Quilted - The tangential surface of the logs in some trees, for example, maple, birch, mahogany, shows a pattern of interlacing grooves.

4. Bird's-eye and dimples - This kind of figure is due to local distortion in fiber alignment that are occasioned by conical indentations in the growth increments.

5. Crotch and stump figures - Twisted grain in large crotches or forks, and stump swells, especially in trees that produce ornamental timber, yield highly figured and valuable veneers.

6. Burl Figures - Obtained from large, abnormal bulges or excrescences that form on the trunk or limbs of nearly any kind of tree.

B. Pigment as a cause of figure

1. Pigment is traceable to irregular streaks and patches of color darker than the background.

2. Pigment figures are reasonably common in our native hardwoods.

IX. Color

Color is caused largely by various infiltrates in the cell wall.

A. Colors can change when exposed to light, air, or heat.

B. Color is a means of timber identification.

C. Color can be modified by special treatment.

X. Luster

Luster is the property of wood which enables it to reflect light. It depends partly on the angle at which the light strikes the surface and the type of cells exposed at the surface.

A. The majority of woods are intermediate in luster.

XI. Odor and Taste

Odor that is present in wood is caused by infiltration products deposited in the heartwood or arises from the action of fungi, bacteria, molds, or yeasts. The action of these micro-organisms on the wood produces odor by either deposits of scented by-products in the wood, or decomposition of the reserve food materials in the parenchyma cells.

A. Deterioration of Food Materials

1. Carbohydrates - Fats - Oils - Odors tend to be particularly evident and usually disagreeable.

B. Aromatic Extractives

1. May be distinctive enough to be useful in identification of wood.

2. Strongly scented woods may smell rancid or like kerosene. Such odors are due to the presence of volatile materials.

3. Prolonged exposure to air and/or water causes a loss of volatile material so that odor is scarcely evident.

4. When using scent as a means of identification, a fresh cut should be made and the surface moistened and warmed slightly in order to make the odor most obvious.

5. The taste of wood is seldom distinctive; but, since the senses of odor and taste are closely related, the combination of them may help in the identification of wood.

6. Incense cedar has a very distinct taste and odor.

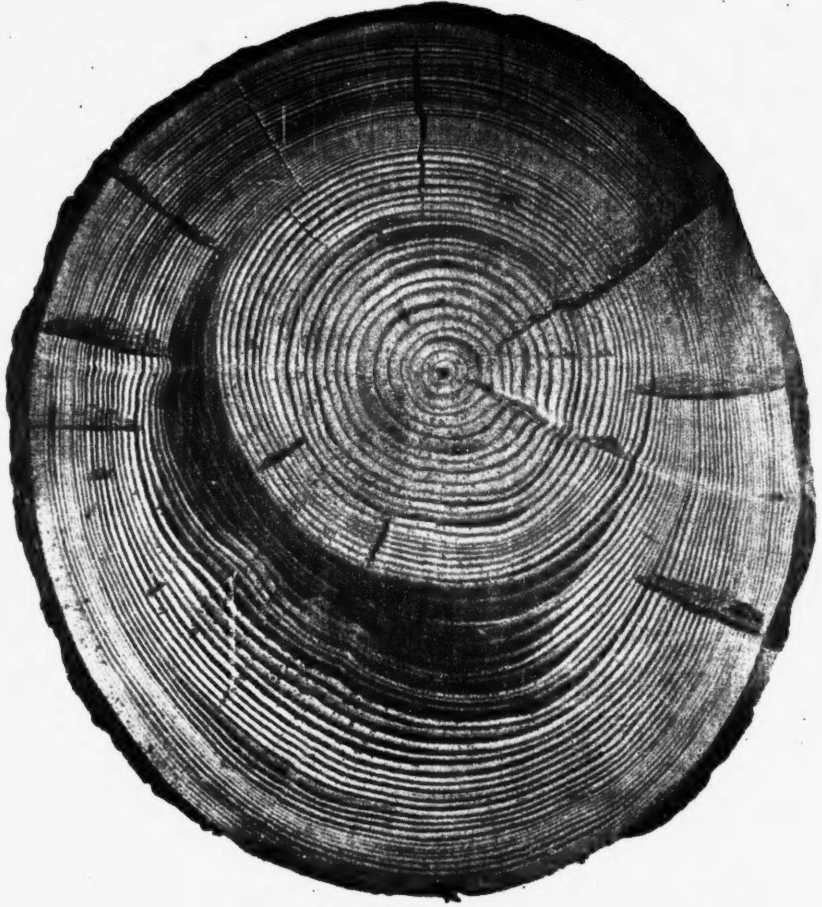

FIG. 1.—Cross-section of spruce log showing compression wood (the dark, wide-ringed portion shown in the lower part of the section).

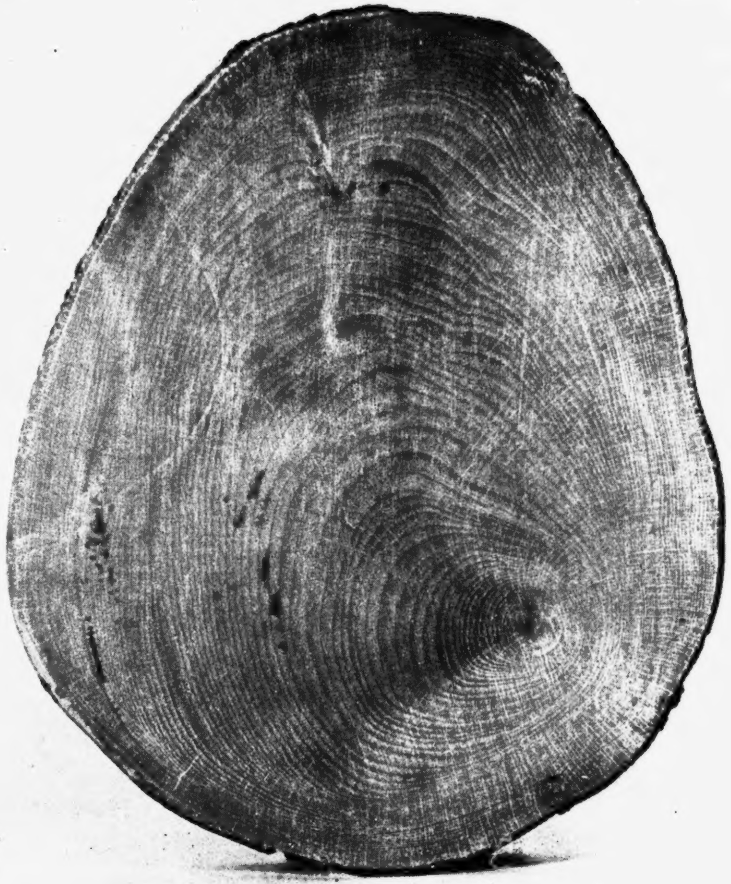

FIG. 2.—Cross-section of beech log showing tension wood

Note : tension wood is formed on the upper side of branches and on the up-hill side of leaning trees, and compression wood on the lower side of branches and the downhill side of leaning trees

Photo by U.S. Forest Products Laboratory

Photo by F.P.R.L., Princes Risborou

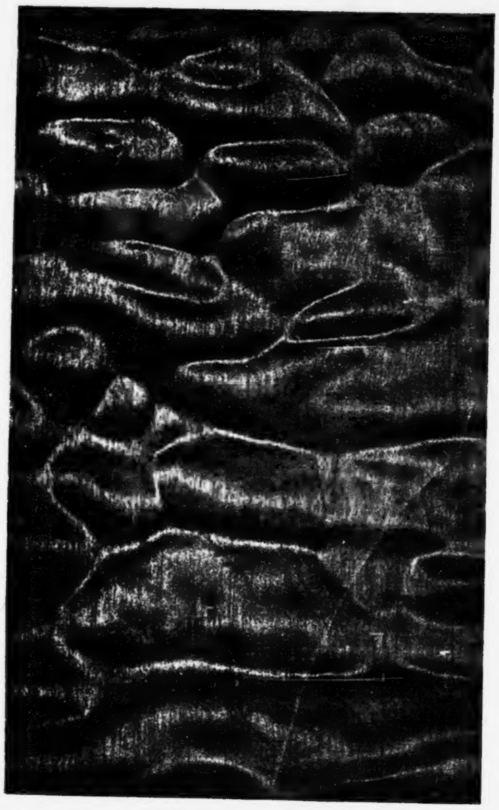

FIG. 1.—Blister figure in Pacific maple

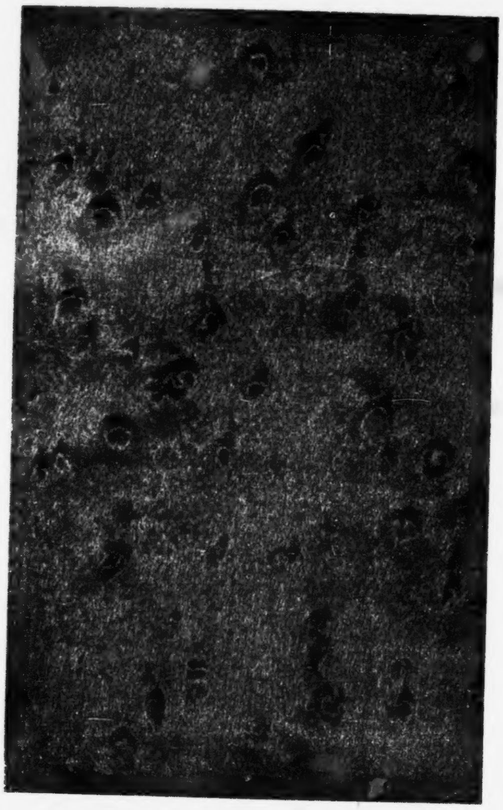

FIG. 2.—Bird's-eye figure in maple

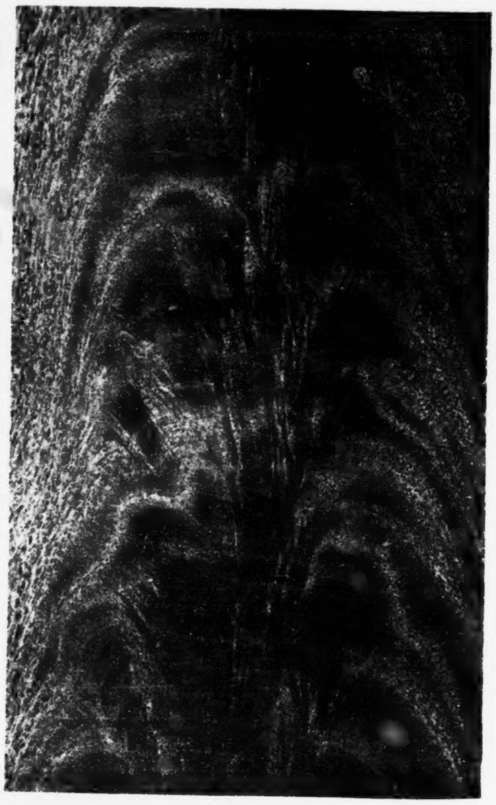

FIG. 3.—Curl figure in Spanish mahogany

Photos by F.P.R.L., Princes Risborough ; veneers lent by Messrs. John Wright (Veneers) & Sons

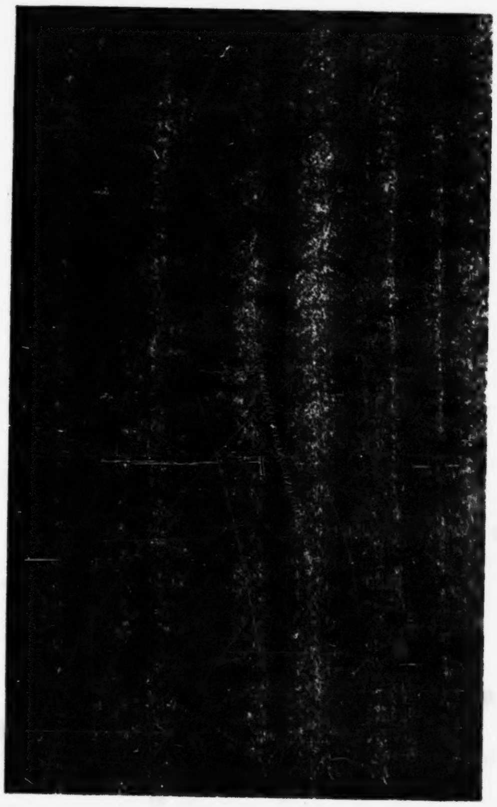

FIG. 1.—Stripe or ribbon figure in African mahogany

By courtesy of E. H. B. Boulton, Esq.

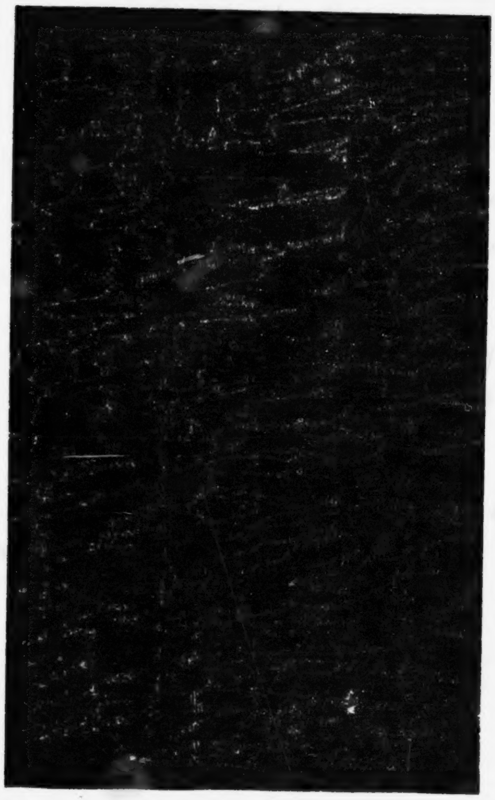

FIG. 2.—Roe figure in mahogany

Photo by F.P.R.L., Princes Risborough ; veneer lent by Messrs. John Wright (Veneers) & Sons

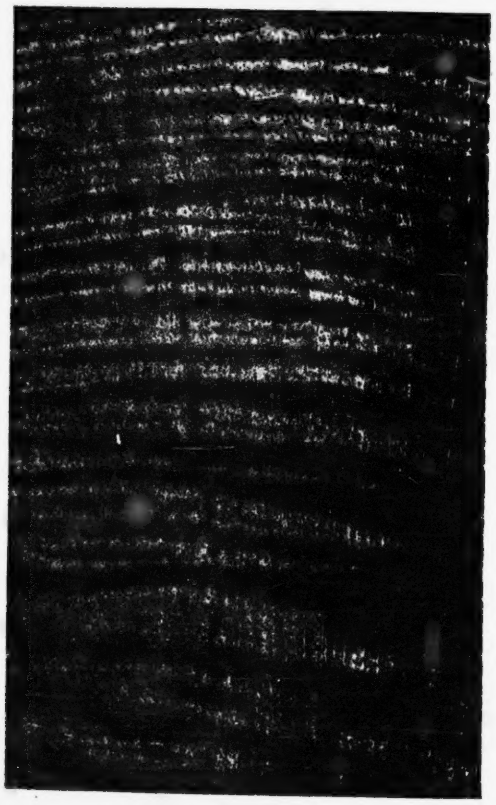

FIG. 3.—Fiddle-back figure in walnut

Photo by F.P.R.L., Princes Risborough ; veneer lent by Messrs. John Wright (Veneers) & Sons

UNIT IV

NATURAL DEFECTS IN WOOD

I. Natural defects are imperfections in the wood of living trees which arise from growth and environment.

  A. Cross grain in wood reduces strength by creating fiber alignment which does not coincide with the longitudinal axis. It occurs in three forms.

    1. Spiral grain is visible as a twisted appearance to the trunk after the bark has been removed.

    2. Interlocked grain is spiral grain which reverses direction in neighboring growth ring.

    3. Diagonal grain causes the grain of the wood to intersect the surface at an angle. A milling defect.

  B. Knots are branch bases that are imbedded in tree trunk wood or in larger limb branch.

    1. Spike knots are cut lengthwise through the branch.

    2. Round knots are cut more nearly at right angles to the long axis of the branch.

      a) Knots normally cause a loss of value to wood due to creating a mechanical weakness in the wood.

      b) In some species of the pines and cedars, they are a desirable attribute because of the pleasing appearance.

  C. Reaction Wood is the specialized type of wood that is produced on the wide side of such eccentric cross sections.

    1. Compression wood is formed in softwoods on the lower or compression stress side of leaning stems.

    2. Tension Wood is usually formed on the upper side of leaning stems or branches of hardwoods.

  D. Growth Stresses are internal stresses in logs evident by pinching, warping and twisting of boards as they are being sawed.

    1. Shakes are a splitting and cracking in the longitudinal plane as a log is cut from a standing tree.

a) Heart shakes are radial plane in direction.

b) Ring shakes form in the plane of the growth increments.

2. Brittle heart is represented by microscopic shear failures lying at 30° to 45° to the fiber axis. If they are large enough to be seen, it is a compression failure.

E. Brashness is an abnormal condition that causes the wood to break suddenly and completely across the grain at stress levels lower than expected, brought about by a decrease in cell wall material. It is caused by abnormal per cent of soft tissues. (Parenchyma Rays)

F. Frost injuries are injuries from freezing temperatures.

1. Frost rings cause discoloration due to injury to the cambium.

2. Frost cracks are radial splits in wood and bark near the base of the tree.

G. Pitch defects are found in softwoods and are accumulations of excessive amounts of resins in localized regions.

H. Bark pockets are small patches of bark imbedded in wood.

UNIT V

THE IDENTIFICATION OF WOOD

I. Broad general wood identification measures. This represents some valuable keys in knowing woods. Some headings are much more useful than others but all have a place in identification.

   A. Growth range of species

   B. Color taking into consideration variations within species as well as that in heartwood and sapwood.

   C. Relationship of amounts of heartwood and sapwood.

   D. Specific gravity values which are a relationship of wood weights to the weight of the displaced volume of water by that species.

   E. Odor is an excellent key in some woods, while taste can have some significance in a few instances.

   F. Grain of wood offers clues which are concerned with the direction of alignment and arrangement of wood elements when looked at in an overall view.

   G. Texture which refers to the size and proportional amounts of woody elements.

      1. Softwoods show texture best in the average tangential diameters of the trachiads.

      2. Hardwoods display the texture in the tangential diameters of vessels and rays.

   H. Lustre enables wood to reflect light, or to put it in another way the property of exhibiting sheen. The terms of comparison are from lustrous to dull.

   I. In a non-technical sense, clues to wood identification can be secured through such mechanical properties as strength, stiffness, hardness, shock-resistance and machine ability.

II. Factors useful in macroidentification of woods, as related to hard and softwoods. Macroidentification is limited to a 10x hand-held lens.

   A. Ring pattern: Ring of wood on a transverse surface resulting from a period of growth; if once such ring a year is formed, it is an annual ring.

      1. Softwoods will show the late wood and early wood pattern to be either abrupt or gradual.

2. Hardwoods will show pore arrangement which is related to the growth rings.

a) Ring porous wood shows the pores formed in the early wood much larger than those in the late wood and as being somewhat abrupt.

b) Diffuse porous wood in which the pores exhibit little or no variation in size within seasonal growth.

B. Cell types are variable in hard and soft woods

1. Softwoods have elongated cells that constitute the greater part of softwood structure. (See Figure 1.)

a) A major cell type is called a trachied.

(1) When viewed in cross section under the microscope, these appear as somewhat angular cells that fit tightly together, with few intercellular spaces.

(2) These possess relatively thick secondary walls.

(3) For an idea of the volume of these cells in wood, white pine is composed of 90 per cent trachieds.

(4) Trachieds serve for both conduction and support.

b) Bordered pits which appear in longitudinal view as openings in the secondary wall, and are able to move water between various trachieds. (See Figure 2.)

c) Vascular rays which are one cell wide and hard to see are present. In soft woods rays make up about 8 per cent of the wood volume.

2. Hardwoods have a different cellular arrangement.

a) Hardwoods have trachieds, but wood fibers, cells of the same general form but considerably modified, are more common.

(1) Wood fibers have smaller cavities than trachieds, are longer and taper more at the ends, and have pits greatly reduced in size.

(2) The function of the fiber is mechanical support, little or no water moves through them.

b) Vessels are tube-like structures of considerable length for water conduction.

(1) Some vessels are compartmented by transverse bars.

(2) Vessels distinguish hardwoods from softwoods.

(a) Vessels in cross section may be seen with the hand lens or naked eye as tiny openings.

(b) Vessels elements also bare pits on the side walls.

c) Parenchyma cells and their patterns are wood identification keys; they are short relatively thin-walled cells. They function in metabolism and storage of plant food materials.

(1) Axial parenchyma occurs in strands along the grain.

(2) They may be visible with a hand lens on the transverse surface of wood as dots, as sheaths around pores, or as broken or continuous lines or bands.

C. Cell alignment in soft and hardwoods

1. Softwoods display a sequential, radial pattern of cells in a transverse section.

2. Hardwoods show no significant patterns, but display cells in a more random pattern.

D. Rays are ribbon-shaped strands of cells which extend radially within a tree and vary in height from several cells to four inches or more in oak.

1. Softwood displays vascular rays which extend in radiating lines from the vicinity of the pith through the wood and being one cell wide are hard to see in macroidentification. (See Figure 3.)

2. Hardwoods show great variety from broad to invisible rays with the naked eye.

a) In a few hardwoods rays are only one cell wide and comparatively few cells high.

b) In most cases they are many cells wide and extend vertically some distance in the wood.

c) Some species have both narrow and wide rays.

3. Rays as seen on a radial surface is expressed as fleck.

E. Resin ducts expose resin in the sapwood of softwoods.

1. Softwoods like the pines, Douglas fir, larch and spruce have horizontal and vertical resin canals.

   a. The canals are lined with living cells that secrete oleoresin.

   b) This material yields turpentine and resin.

   c) Not all softwoods have resin ducts.

2. Hardwoods do not show the presence of resin ducts.

F. Tyloses is an identifying feature particularly in white oak. This material is a crystalline material that normally develops in a vessel and seals the grain against air passage.

III. Softwood - Broad identification classification based on resin ducts and odor.

A. Resin ducts present. (See Table 1)

1. Numerous - Lodgepole pine
Ponderosa pine
Sitka spruce
Southern pine
Sugar pine
White pine

2. Not numerous - Spruce
Engelmann
Red
White
Douglas fir
Larch
Eastern Tamarack
Western

B. Non-Resinous. (See Table 2)

1. Odor present - Cedar
Alaska Yellow
Port Oxford White
California Incense
Western
Eastern Red cedar
Northern White cedar
Baldcypress

2. Odor not present - Fir
Eastern Balsam
Western Balsam
California
Noble
Hemlock
Eastern
Western
Redwood

IV. Hardwoods - Broad identification classification based on ring and diffuse porous and rays.

A. Ring porous (See Table 3)

1. Broad rays present - Oak
Red group
White group

2. Broad rays absent
    - American chestnut
    - American elm
    - Aspen
    - Black ash
    - Black cherry
    - Black locust
    - Black walnut
    - Butternut
    - Cottonwood
    - Green ash
    - Hackberry
    - Pecan hickories
    - Red elm
    - Rock elm
    - True hickories
    - White ash
    - Willow

B. Diffuse porous. (See Table 4)

1. Wide rays present - American sycamore
    - Beech
    - Red Alder

2. Wide rays absent
    - Aspen
    - Basswood
    - Birches
    - Black Cherry
    - Black Gum
    - Black Walnut
    - Butternut
    - Cottonwood
    - Cucumbertree
    - Hard Maples
    - Soft Maples
    - Southern Magnolia
    - Sweetgum
    - Tupelo Gum
    - Yellow-Poplar

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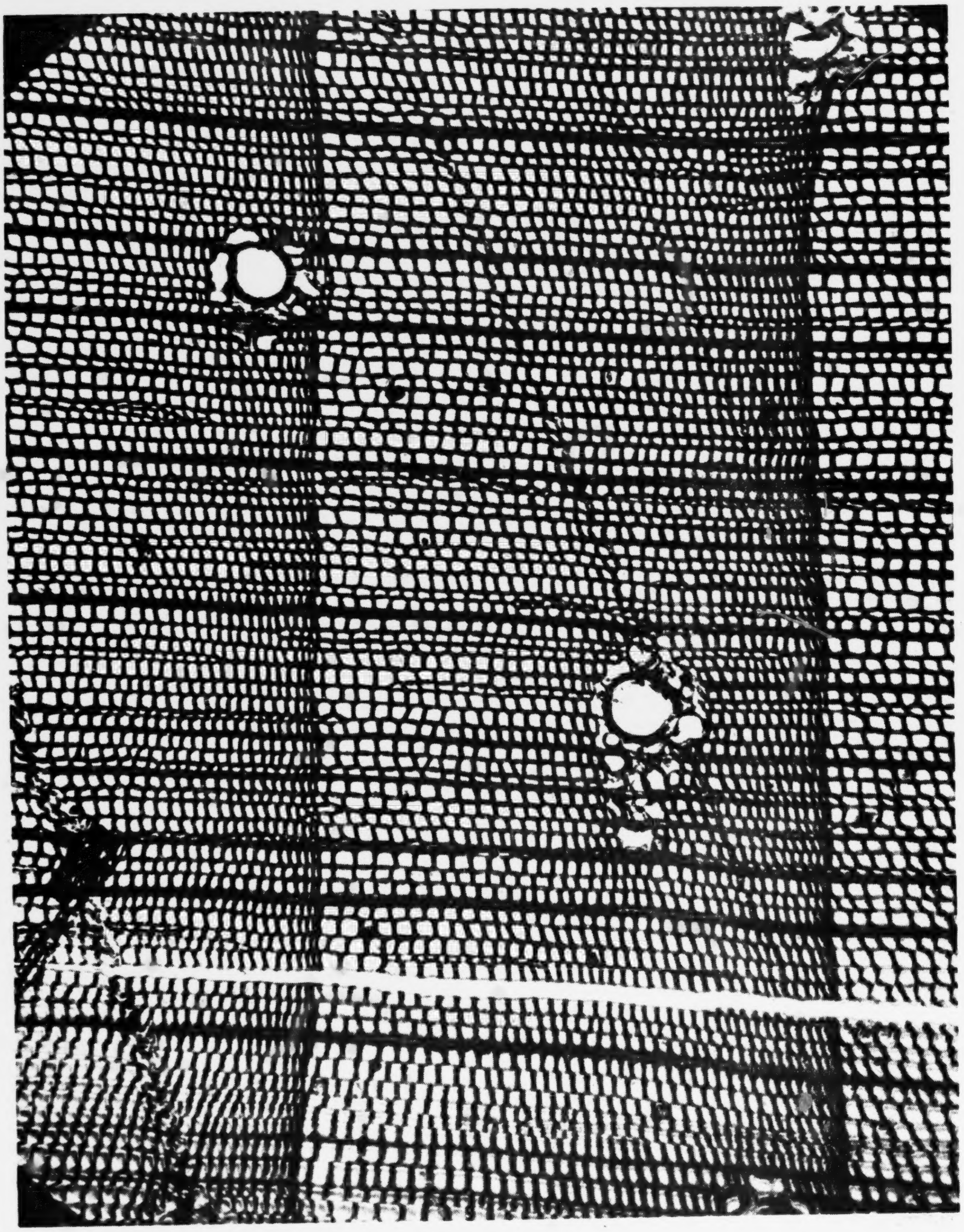


Figure 1. Ponderosa Pine 8x
Transverse Section

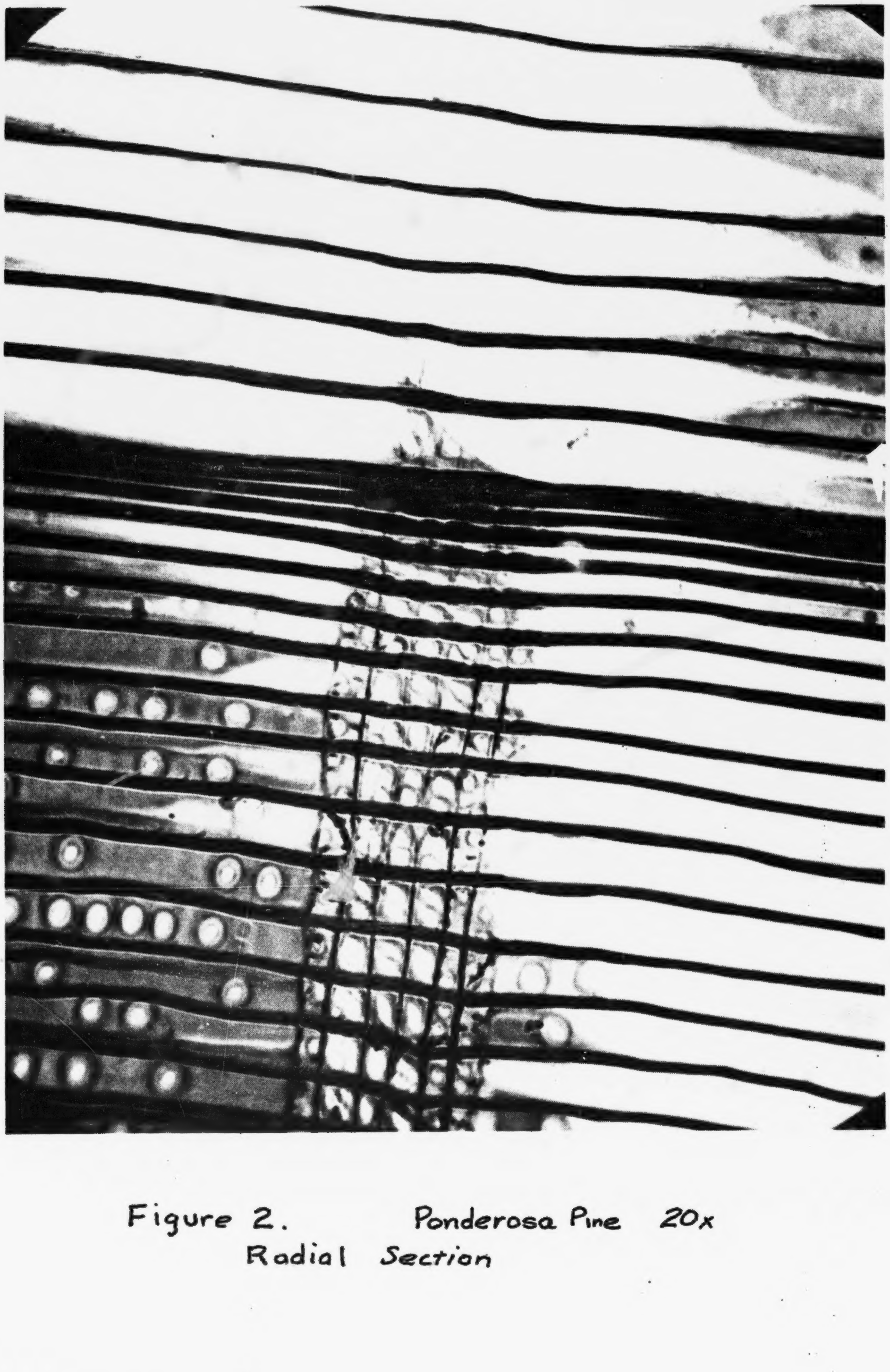
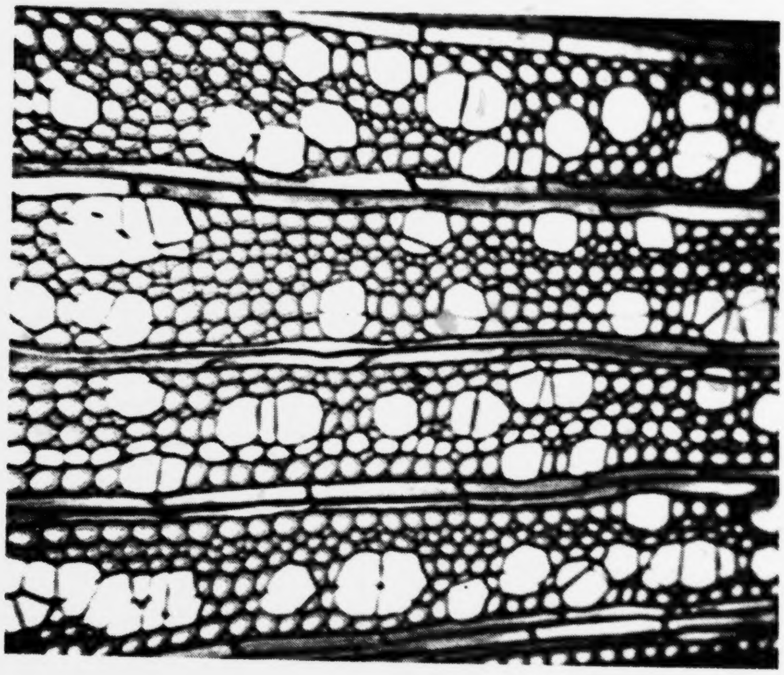
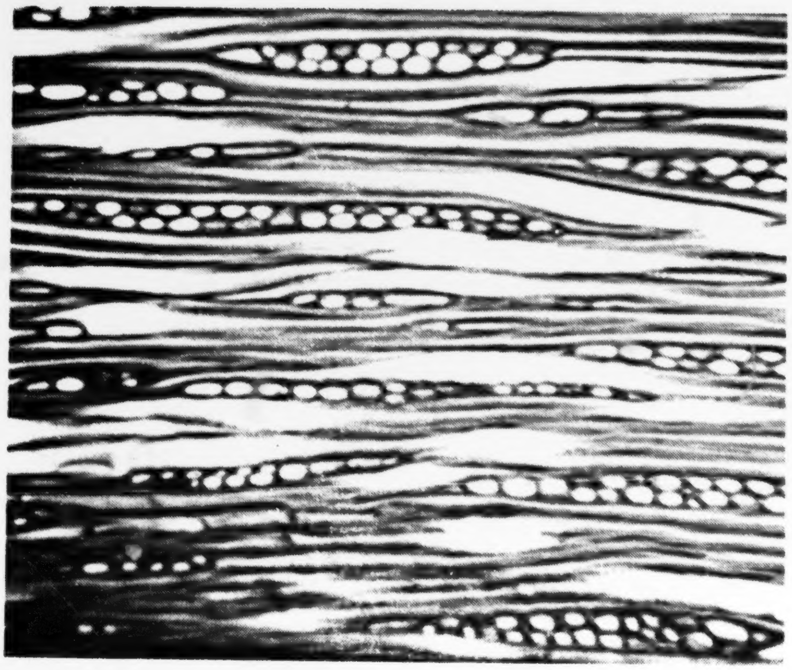


Figure 2. Ponderosa Pine 20x
Radial Section





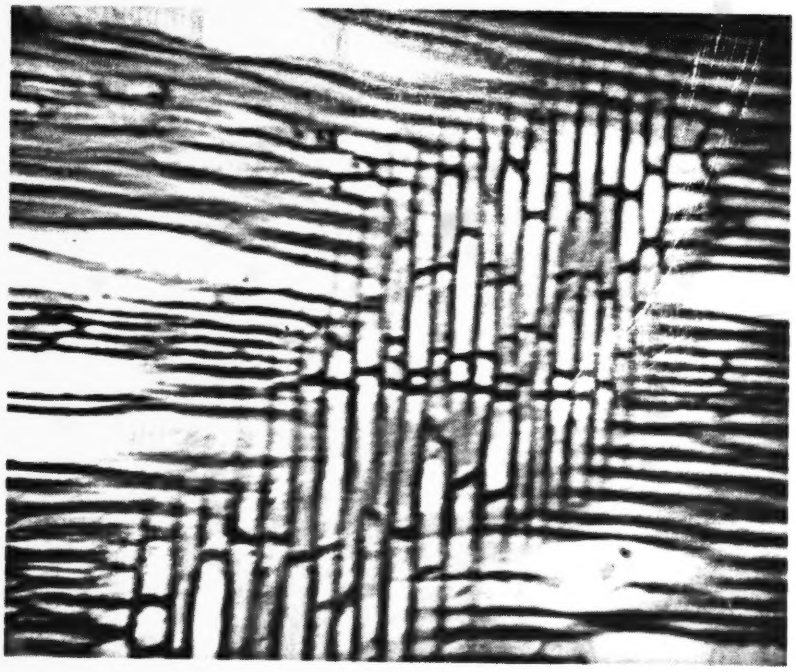


Table 1. SOFTWOODS WITH RESIN CANALS

Transition from Spring to Summerwood Abrupt				*Transition from Spring to Summerwood Relatively Gradual*					
Resin Canals Relatively Small		*Resin Canals Medium to Large*		*Resin Canals Relatively Small*			*Resin Canals Medium to Large*		
							Coarse Texture Large Canals		*Medium to Coarse Texture*
WESTERN LARCH *Larix occidentalis*	DOUGLAS FIR *Pseudotsuga menziesii*	PONDEROSA PINE *Pinus ponderosa*	SOUTHERN YELLOW PINE *Pinus taeda echinata palustris elliottii etc.*	DOUGLAS FIR	EASTERN SPRUCE *Picea species*	SITKA SPRUCE *Picea sitchensis*	SITKA SPRUCE	SUGAR PINE *Pinus lambertiana*	WHITE PINE *Pinus strabus or monticola*
Wood hard and brittle Heartwood russet brown Annual rings usually narrow and even	Wood medium hard and not brittle Heartwood orange-red to reddish-yellow Characteristic odor May have wide growth rings	Summerwood band narrow Summerwood cuts easily May be dimpled on split tangential surface	Summerwood usually narrow to wide Summerwood usually hard to cut	Hard Heart orange-red to yellow Wide growth rings	Soft pale yellow or cream color Resin canals may be in tang. row	Wood soft pinkish to lilac tinge May be dimpled on tangential split surface	Pinkish to pale brown No resin odor May be dimpled on tang. split surface	White to pale reddish-brown Brown streaks on side grain surface	Heartwood light colored Resin canals not as distinct as in sugar pine Streaks on side grain not pronounced

Table-2. SOFTWOODS WITHOUT RESIN CANALS

Wood with Pleasant Distinctive Odor		Wood without Pleasant Distinctive Odor				
Fine Texture	Medium to Coarse Texture	Transition between Spring and Summerwood Abrupt		Transition between Spring and Summerwood is less abrupt		
		REGULAR SPACING OF GROWTH RINGS	IRREGULAR SPACING OF GROWTH RINGS	HEARTWOOD WITH ROSE STREAKS. PIN KNOTS FREQUENT	HEARTWOOD LIGHT REDDISH-BROWN OR PURPLISH	HEARTWOOD USUALLY WHITISH
EASTERN REDCEDAR *Juniperus virginiana*	WESTERN REDCEDAR *Thuja plicata*	REDWOOD *Sequoia sempervirens*	BALDCYPRESS *Taxodium distichum*	PARANA PINE *Araucaria angustifolia*	WESTERN HEMLOCK *Tsuga heterophylla*	TRUE FIR *Abies species*
Heartwood purplish or reddish	Heartwood is reddish or pinkish-brown to dull brown	Heartwood is deep reddish brown	Heartwood blackish brown, reddish brown, pale brown, or whitish		Summerwood usually a darker shade of springwood	Wood is relatively soft and easy to carve
	Transition from spring to summerwood is more or less abrupt	Coarse textured	Fine to coarse texture		Wood somewhat brittle but not nearly as brittle as E. hemlock	Transition between spring and summerwood is more gradual than in hemlock
The E. redcedar is easier to cut across the grain with a knife - mostly because of its finer texture			Heartwood of darker shades, is often greasy to touch and may have a rancid odor			

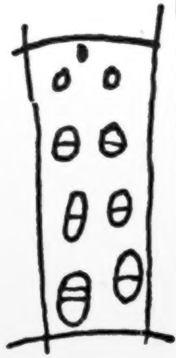
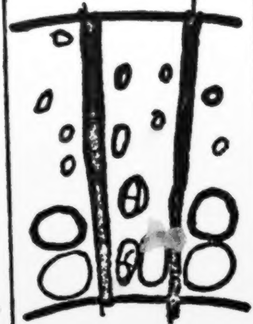
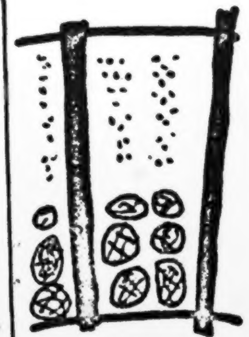
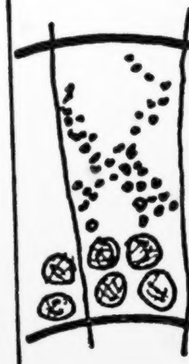
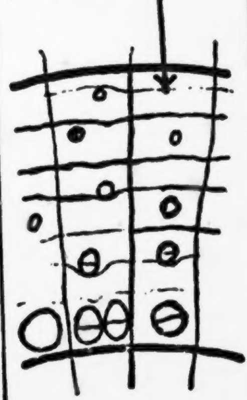
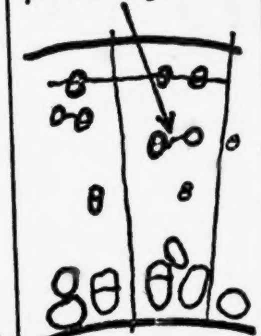
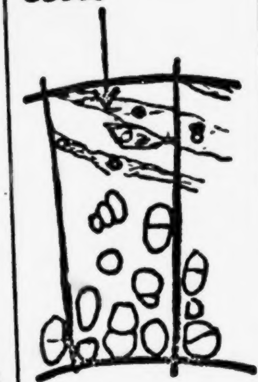
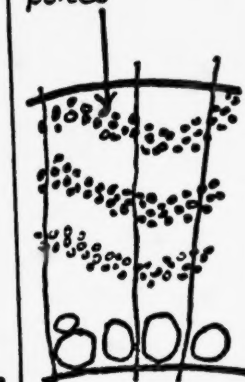
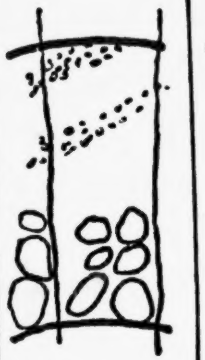
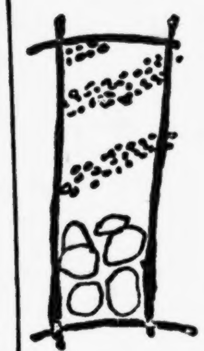
SEMI-RING POROUS HARDWOODS	Table 3. RING POROUS HARDWOODS								
	Summerwood pores in 'V' or flame-shaped patches of parenchyma			*Thin lines of parenchyma in summerwood running parallel to growth rings*	*Last groups of summerwood pores connected by lines of parenchyma running parallel to growth rings*		*Summerwood pores bunched in series of wavy rows running roughly parallel with springwood pores*		
	Wide rays-width of rays approaches width of springwood pores		*Narrow rays*		Rays not clearly visible on cross-section without the aid of a hand lens	Rays clearly visible on cross-section with naked eye	*Springwood band of pores generally one pore wide*	*Springwood band of pores 2-5 cells wide*	
Number of summerwood pores relatively easy to count	Number of summerwood pores relatively difficult to count								
BLACK WALNUT *Juglans nigra*	RED OAK *Quercus rubra*	WHITE OAK *Quercus alba*	CHESTNUT *Castanea dentata*	TRUE HICKORY *Carya species*	ASH *Fraxinus species*	HONEYLOCUST *Gleditsia triacanthos*	AMERICAN ELM *Ulmus americana*	SLIPPERY ELM *Ulmus rubra*	HACKBERRY *Celtis occidentalis*
Heartwood light brown to purplish. Tyloses. Faint odor	Tyloses usually absent. Largest rays rarely 1½" tall (avg ¼"-½" tall). Heartwood usually reddish or light brown	Tyloses usually present. Largest rays frequently 1½" tall (avg ½" - 1¼"). Heartwood usually grayish-brown to dark brown	Width of rays much less than width of springwood pores. Tyloses abundant	Lines of parenchyma crossing rays form little squares in summerwood. Wood hard. Some pieces of hickory may tend toward diffuse porous	Summerwood pores easily visible with hand lens. Heartwood light brown, occasionally pale yellow in white ash. Heartwood grayish-brown to dark brown in black ash	Heartwood light red to reddish-brown summerwood sometimes indistinct even with hand lens. Wavy pattern in summerwood frequently made by parenchyma cells	Heartwood light brown to brown. Springwood pores plainly visible with a hand lens.	Heartwood dull or dark brown Rays about same width as average summerwood pores	Heartwood yellowish to light brown. Rays often as wide as smaller springwood pores
									

Table 4. DIFFUSE POROUS HARDWOODS

RAYS WIDE: READILY VISIBLE ON CROSS-SECTION WITHOUT MAGNIFICATION							RAYS NARROW: GENERALLY VISIBLE ONLY WITH MAGNIFICATION							
Individual rays prominent on tangential surface		*Individual rays not prominent on tangential surface*					*Larger pores visible without magnification*				*Larger pores only visible with magnification*			
Rays appear to occupy less than half of area on radial or tangential surface	Rays appear to occupy more than half of area on radial or tangential surface	Heartwood brown to reddish brown usually darker shades of brown		Heartwood light tan, white, purplish, green, or black			Deep pore paths clearly visible on radial and tangential surfaces		Deep pore paths not clearly visible on radial and tangential surfaces		Usually 3 or more pore widths between rays; ray fleck often visible on radial surface	Usually only one or two pore widths between rays; ray fleck not generally visible on radial surface		
BEECH *Fagus grandifolia*	SYCAMORE *Platanus occidentalis*	Deep pore paths clearly visible on radial and tangential surfaces	Deep pore paths lacking on radial and tangential surfaces	End of growth ring terminated by prominent white line of parenchyma cells	End of growth ring not terminated by prominent white line of parenchyma cells		Ends of growth rings distinct; frequently has ripple marks on tangential surface	Ends of growth rings not distinct; tangential rows of resin canals usually visible on cross-section	Wood light to moderately light in weight; easy to dent with fingernail	Wood heavy to very heavy in weight; not easy to dent with fingernail	BASSWOOD *Tilia americana*	Pore volume occupies half or more of cross-section area; growth rings usually not distinct to naked eye		Pore volume occupies less than one-half of cross section area; growth rings usually distinct to naked eye
Individual rays clearly visible on tangential surface. Summerwood pores small and scattered often difficult to see	Broad band of cells at end of growth ring	HONDURAS MAHOGANY *Swietenia macrophylla*	BLACK CHERRY *Prunus serotina*	YELLOW POPLAR *Liriodendron tulipifera*	Larger rays appear wider than larger pores	Larger rays appear about same width as larger pores	HONDURAS MAHOGANY *Swietenia macrophylla*	PHILLIPINE MAHOGANY *Shorea species*	COTTONWOOD *Populus species*	YELLOW BIRCH *Betula alleghaniensis*	White lines of parenchyma distinct at end of growth ring. Heartwood yellowish brown. Rays distinct with hand lens	Heartwood shades of gray	Heartwood shades of red	ASPEN *Populus species*
		Frequently has ripple marks on tangential surface	First pores in springwood often in a single line parallel to growth rings	Heartwood often green, black, or yellow	HARD MAPLE *Acer species*	SOFT MAPLE *Acer species*	Heartwood dark reddish-brown to shades of light creamy-brown. Frequently have interlocking grain which produces ribbon or stripe figure on radial surface		Rays difficult to see even with hand lens. Springwood pores oval-shaped. Tending toward semi-ring porous	Rays distinct with hand lens		BLACK GUM *Nyssa species*	RED GUM *Liquidambar styraciflua*	Rays indistinct even with hand lens. One of whitest hardwoods. Similar in appearance to cottonwood but with smaller pores
					Pore size is about the same in both maples but hard maple has wider rays. Hard maple is frequently harder than soft maple. Soft maple may have purplish tinge							Interlocking grain often evident on radial surface of larger pieces		
											Soft maple may sometimes key down to this point but can usually be differentiated because of its ray fleck and difference in color from these woods			

CALIFORNIA STATE COLLEGE
LONG BEACH

WOOD TECHNOLOGY

WOOD IDENTIFICATION

Purpose: To provide experience in the scientific identification and classification of woods through the use of key and punch cards.

Apparatus required:

Magnifying glass
Knife
Paper punch
Scissors
Sorting Pin
Reference Key
Pen and Black Ink
15 Identification Punch Cards
15 Wood Samples

Experiment:

1. Evaluate and identify at least 15 different woods.
2. Punch out the identification cards using the Paramount Multiple Entry key as a reference.
3. Label the punch cards with the botanical and common names of the samples.
4. Design and construct an expandable filing system that will hold about 100 - 5 x 8 cards.

Questions:

1. What is a wood identification key?
2. What is the principle employed in the wood identification process?
3. How does the punch card system of identification utilize this process?

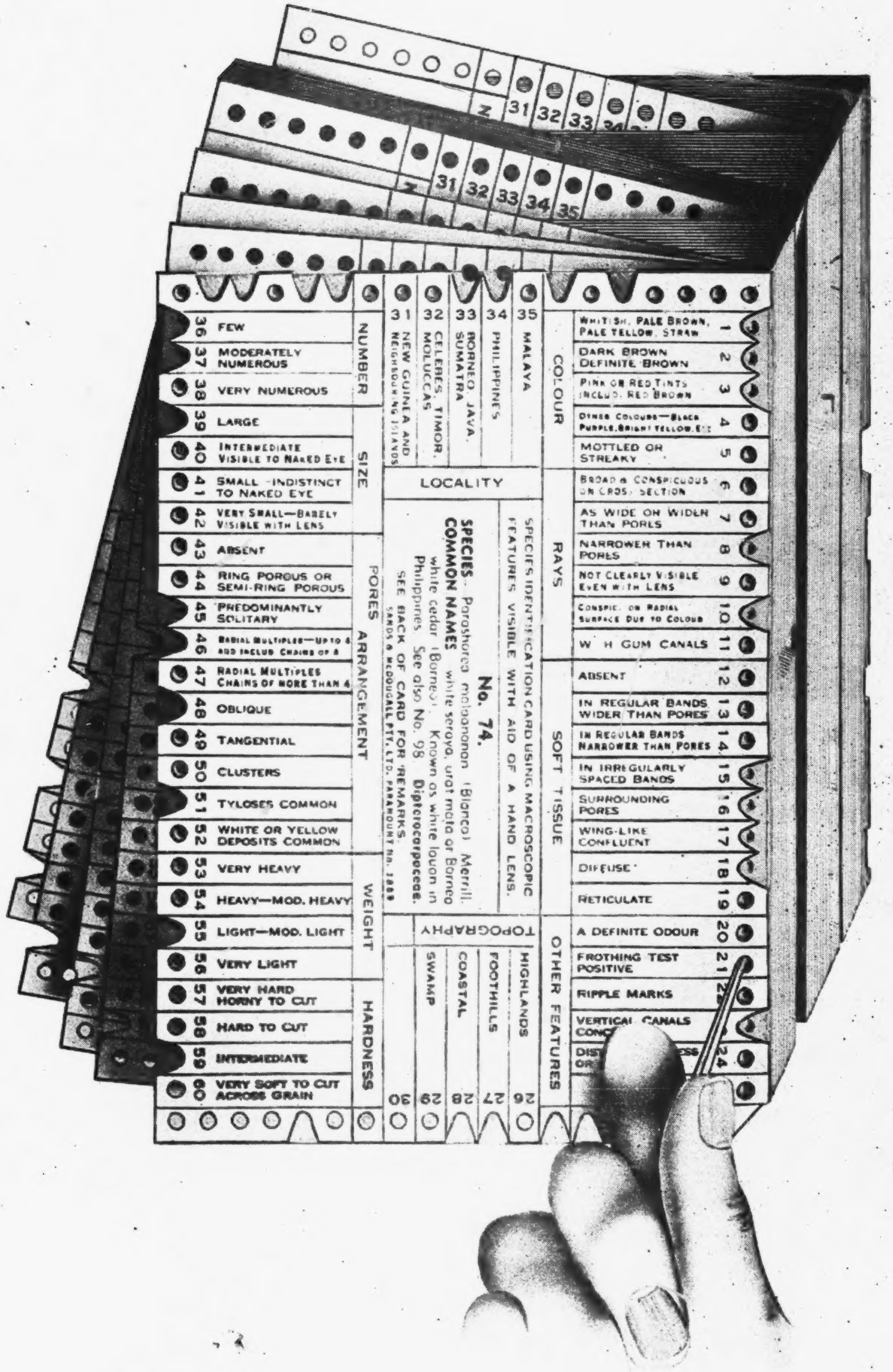
References:

Panshin, Zeeum, Brown, Textbook of Wood Technology

Desch, H. E., Timber, Its Structure and Properties

References:

Holtrop and Hjorth, Principles of Woodworking
US Dept. of Agriculture, Wood Handbook No. 72
Barnes and Noble, General Botany


1 WHITISH, PALE BROWN, PALE YELLOW, STRAW
2 DARK BROWN DEFINITE BROWN
3 PINK OR RED TINTS INCLUD. RED BROWN
4 OTHER COLOURS—BLACK PURPLE, BRIGHT YELLOW, ETC
5 MOTTLED OR STREAKY
COLOUR
6 BROAD & CONSPICUOUS ON CROSS SECTION
7 AS WIDE OR WIDER THAN PORES
8 NARROWER THAN PORES
9 NOT CLEARLY VISIBLE EVEN WITH LENS
10 CONSPIC. ON RADIAL SURFACE DUE TO COLOUR
11 WITH GUM CANALS
RAYS
12 ABSENT
13 IN REGULAR BANDS WIDER THAN PORES
14 IN REGULAR BANDS NARROWER THAN PORES
15 IN IRREGULARLY SPACED BANDS
16 SURROUNDING PORES
17 WING-LIKE CONFLUENT
18 DIFFUSE
19 RETICULATE
SOFT TISSUE
20 A DEFINITE ODOUR
21 FROTHING TEST POSITIVE
22 RIPPLE MARKS
23 VERTICAL CANALS CONC
24 DIST
OTHER FEATURES
26 HIGHLANDS
27 FOOTHILLS
28 COASTAL
29 SWAMP
30
TOPOGRAPHY
31 NEW GUINEA AND NEIGHBOURING ISLANDS
32 CELEBES, TIMOR, MOLUCCAS
33 BORNEO, JAVA, SUMATRA
34 PHILIPPINES
35 MALAYA
LOCALITY
SPECIES IDENTIFICATION CARD USING MACROSCOPIC FEATURES VISIBLE WITH AID OF A HAND LENS.
No. 74.
SPECIES Parashorea malaanonan (Blanco) Merrill.
COMMON NAMES white seraya, urat mata or Borneo white cedar (Borneo). Known as white lauan in Philippines. See also No. 98 Dipterocarpaceae.
SEE BACK OF CARD FOR 'REMARKS.'
36 FEW
37 MODERATELY NUMEROUS
38 VERY NUMEROUS
NUMBER
39 LARGE
40 INTERMEDIATE VISIBLE TO NAKED EYE
41 SMALL—INDISTINCT TO NAKED EYE
42 VERY SMALL—BARELY VISIBLE WITH LENS
43 ABSENT
SIZE
44 RING POROUS OR SEMI-RING POROUS
45 PREDOMINANTLY SOLITARY
46 RADIAL MULTIPLES—UP TO 4 AND INCLUD. CHAINS OF 4
47 RADIAL MULTIPLES CHAINS OF MORE THAN 4
48 OBLIQUE
49 TANGENTIAL
50 CLUSTERS
PORES ARRANGEMENT
51 TYLOSES COMMON
52 WHITE OR YELLOW DEPOSITS COMMON
53 VERY HEAVY
54 HEAVY—MOD. HEAVY
55 LIGHT—MOD. LIGHT
56 VERY LIGHT
WEIGHT
57 VERY HARD HORNY TO CUT
58 HARD TO CUT
59 INTERMEDIATE
60 VERY SOFT TO CUT ACROSS GRAIN
HARDNESS

The multiple entry card-key in operation

By courtesy of the Cleaver-Hume Press, Ltd.

Some Record Trees

For the record, bigness in trees is arrived at by adding the circumference in inches, the total height in feet, and one quarter of the crown spread in feet. Thus a very tall, very slender tree may not be the biggest of its species; the total growth remains the criterion. These champions were chosen from a list compiled by The American Forestry Association. The list is kept up to date as larger champions are discovered and reported by observers all over the country. Anyone discovering a record tree may write to: The American Forestry Association, 919 17th Street, N.W., Washington 6, D.C.

SPECIES	CIRCUMFERENCE AT 4 1/2 FEET	HEIGHT	SPREAD	LOCATION
ALDER, Red or Oregon	11'-6 1/2"	89'	67'	Olympic National Park, Washington
ASH, Green	14'-5"	105'	79'	Big Oak Tree State Park, Missouri
White	22'-3"	80'	82'	Glen Mills, Pennsylvania
ASPEN, Bigtooth	9'-11"	90'	75'	Rocks, Maryland
BALD CYPRESS, Common	39'-8"	122'-6"	47'	Weakley County, Tennessee
BEECH, American	12'-10"	126'	--	West Feliciana Parish, Louisiana
BIRCH, Paper	10'-11"	96'	93'	Lake Leelanau, Michigan
BUCKEYE, Ohio	9'-11"	90'	33'	Near Dayton, Ohio
CHERRY, Black	23'-4"	102'	89'	Lawrence, Michigan
CHESTNUT, American	15'-3 1/2"	72'	67'	Near Chelsea, Michigan
CYPRESS, Arizona	17'-5"	102'	38'	Coronado National Forest, Arizona
DOGWOOD, Flowering	5'-4"	30'	42'	Near Oriole, Maryland
Pacific or Western	6'-11"	100'	45'	Milwaukie, Oregon
DOUGLAS FIR, Common	53'-4"	221'	61'	Olympic National Park, Washington
ELM, American or White	24'-7"	160'	147'	Near Trigonia, Tennessee
FIR, Cascades or Pacific Silver	26'-3"	245'	54'	Olympic National Park, Washington
Noble	22'-8"	260'	35'	Columbia National Forest, Washington
Red or California Red	26'-3"	177'	--	Calaveras County, California
White	25'-5"	189'	--	Yosemite National Park, California
HEMLOCK, Canada or Eastern	19'-9"	98'	69'	Great Smoky Mountains National Park, Tennessee
HICKORY, Shellbark	12'-9"	122'	70'	Big Oak Tree State Park, Missouri
HOLLY, American	13'-4"	53'	61'	Near Hardin, Texas
HONEY LOCUST, Common	18'-9"	92'	112'	Near Queenstown, Maryland
LARCH, Eastern or Tamarack	11'-5"	60'	60'	Chaplin, Connecticut
LINDEN: BASSWOOD, American	16'-11"	113'	67'	Grand Traverse County, Michigan
LOCUST, Black	15'-11"	85'	60'	Near Jefferson, Indiana
MAPLE, Red	20'-8 1/2"	60'	50'	Annandale-on-Hudson, New York
Silver	22'-10"	110'	93'	Felicity, Ohio
Sugar	19'-9"	116'	75'	Garrett County, Maryland
OAK, Black	19'-9"	90'	138'	Lloyd Neck, New York
Bur or Mossy Cup	20'-9"	110'	107'	Algonac, Michigan
Live	35'	78'	168'	Near Hahnville, Louisiana
Pin	16'	135'	135'	Saint Davids, Pennsylvania
PECAN	21'-4"	135'	145'	Assumption Parish, Louisiana
PERSIMMON, Common	13'-1/2"	80'	73'-6"	Near Johnson, Indiana
PINE, Jeffrey	19'-10"	151'	40'	Los Padres National Forest, California
Loblolly	16'-6"	128'	64'	Near Ammon, Virginia
Ponderosa	27'-1"	162'	--	Near Lapine, Oregon
Shortleaf	10'-7"	146'	60'	Morganton, North Carolina
Sugar	32'-8"	220'	61'	Stanislaus National Forest, California
Western White	21'-3"	219'	36'	Near Elk River, Idaho
PLANE TREE: SYCAMORE, American	32'-10"	80'	102'	Near South Bloomfield, Ohio
POPLAR: COTTONWOOD, Eastern	30'	90'	--	Kearney, Nebraska
RED CEDAR, Eastern	13'-4"	62'	42'	Cumberstone, Maryland
REDWOOD, Coast	65'-9" (at 6')	300'	-	On Redwood Highway, California
SASSAFRAS, Common	16'	88'-6"	68'	Owensboro, Kentucky
SEQUOIA, Giant	101'-6" (at base)	272'	90'	Sequoia National Park, California
SPRUCE, Colorado or Blue	11'-9"	123'	--	Gunnison National Forest, Colorado
Engelmann	19'-11"	104'	30'	Cache National Forest, Idaho
Sitka	51'-6"	180'	50'	Olympic National Park, Washington
TULIP TREE: YELLOW POPLAR	26'-6"	83'	98'	Annapolis, Maryland
TUPELO, Black or Blackgum	15'-9"	130'	100'	Near Urania, Louisiana
WALNUT, Eastern Black	20'-3"	108'	128'	Ann Arundel County, Maryland
WILLOW, Black	26'-1"	85'	79'	Traverse City, Michigan

The Physical Nature of Wood
Hygroscopicity

I. Wood is hygroscopic in nature.

A. It is an affinity for water and can contain it in two states:

1. Hygroscopic water is that water which is bound by the cellulose within the cell walls.
2. Free water is water which is found in liquid form and contained by the cell structure intracellular (within the lumins) or intercellular (between the cell walls).

B. Because wood is hygrosocopic, it Moves.

1. Movement in wood is change of size and/or shape due to shrinkage or swelling. Also known as "working".

a.)Movement can only occur below the fibre saturation point (25-30% moisture content) at which there is no free water present and the loss or gain in moisture content is related to hygroscopic moisture alone.
b.)When wood contains free water, it is considered green.

2. Movement in wood is anisotropic (also, differential shrinkage)

a.)It has varying rates of shrinkage dependent on the axis upon which it is measured.
b.)The anisotropic rates of shrinkage are approximately:

(1) Transverse direction (parallel to the grain)
0 to 1% (from wet or green to K.D.)
(2) Radial direction (from pith to bark)
6 to 8% (from green to K.D. condition)
(3) Tangential direction (along the annual ring)
13 to 15% (from green to K.D. condition)

c.)This anisotropic response to moisture is the main cause for problems in wood utilization. (See "Seasoning and Seasoning Degrade in wood")

3. The prevention of movement in wood, or stabilization has been the subject of research to woodworkers for centuries.

a.)The simplist, but least effective means has been to apply a protective film over the wood. (paint, varnish, etc.)

b.)See "Protecting and Preserving Wood In Service"

4. The typical response of wood to the seasoning process is illustrated in figures 2 and 3 in the chapter "Moisture Content in Wood"

C. An experiment which demonstrates the hygroscopicity of wood may be conducted with simple apparatus as exampled by that performed by students within the Wood Technology Program at California State College, Long Beach. The accompanying outline may be utilized as is or modified to suit the instructor's purpose.

California State College
Wood Technology
Experiment
Hygroscopic Nature of Wood

Purpose: To stress the importance of adequate knowledge of the hygroscopic nature of wood in the design and development of wood products.

Apparatus Required:

1 inch micrometer
oven
balance
8 - 7/8 inch wood cubes
8 plastic bags
3 refrigerator (double wall) paper bags
glass jar
water
graph supplies

Experiment:

1. Carefully machine sand the wood cubes to exact 7/8'' size.

2. Oven dry two of the samples and determine the moisture content for all eight samples.

3. Weight measure and label the blocks. Each block should have a number (1-8) and the sides of the block should have a letter (transverse - A) (radial - B) (Tangential - C) A ball pen can be used for the labeling process.

4. Completely submerge the two blocks that were oven dried, plus two additional blocks, in water.

5. Expose two of the blocks to outdoor elements on the shaded north side of a building. Be sure to pick a safe location.

6. Place the two remaining blocks in a normal room atmosphere.

7. After ten days, collect the samples and seal each group individually in a plastic bag. Package the three groups in separate freezer bags and bring them to class on the day of collection. Again, weigh and measure the blocks.

8. Record and evaluate the moisture and measurement changes in the blocks. Use the bar graph to compare the results. Be sure to include a comparison of changes in size of the various sections. Equate in percentage scores.

Questions:

1. Was there a significant difference in the changes in weight and measurement between the two oven dried samples and the two other submerged samples?
2. What is the significance of this study to an industrial arts teacher or craftsman?
3. What is meant by "maximum moisture content"?
4. What is meant by "moisture gradient"?
5. What is the "fiber saturation point"?
6. What is meant by "moisture equilibrium"?
7. What is meant by the term "hygroscopic nature of wood"?
8. How does a board absorb and release moisture?
9. What can be done to reduce the absorption of moisture in wood products?
10. What is meant by the term "conditioning wood joints"?
11. In which direction does wood expand the greatest amount when subjected to moisture? The least amount? Reference this question to the transverse, radial and tangential sections.

References:

Holtrop and Hjorth, Principles of Woodworking

Panshin, Zeuun, Brown, Textbook of Wood Technology

U. S. Department of Agriculture. Wood Handbook No. 72

Desch, H.E., Timber, Its Structure and Properties

DENSITY IN WOOD

I. Density in wood is usually exprssed in terms of weight per unit volume volume.
  A. On the continent - grams per cubic centimeter.
  B. In the United States - pounds per cubic foot.

II. Determination of density
  A. Accomplished by dividing the weight by the volume.
  B. Weight is obtained through the use of either balance or a pair of scales.
  C. Volume is determined through direct measurement of the specimen which should not be less than 3" x 2" x 1".(Timber, Its Structure and Properties, p.110)
  D. The formulas for finding density are:
    1.

$$\frac{\text{weight in grams}}{\text{volume in C.C.}} \quad \text{or} \quad \frac{\text{weight in pounds}}{\text{volume in cubic feet}}$$

    2. Smaller samples than 3x2x1 may be used to determine density if the immersion method is used; (Timber, Its Structure...)
      a. Place a beaker of water on a pan or balance and counterbalance with sand or weights.
      b. Suspend the test block, completely submerged, by a needle which in turn is clamped to a stand. Do this without overflowing water from beaker, and without block in contact with the sides. Seal the block before immersion.
      c. Add weights to the counterbalance pan until equilibrium is restored. The weight in grams added is equal to the volume of the test block (water is 1 gram/CC)
      d. Utilize the following formulas:
        (1)

$$\frac{\text{weight of block in grams}}{\text{Weight in grams added to restore balance}}$$

        (2)

$$\frac{\text{Weight of block in pounds}}{\text{Weight in ounces added to restore balance x 0.001}}$$

III. **Specific gravity** may be determined through the use of the following graph after the density has been found in lbs./cu.ft. or by employing the accompanying experiment which must be limited to buoyable specimens.
  A. The specific gravity of the cell wall material in all woods is approximately 1.5 (1½ times the weight of equal volume of water) or about 94 lbs/cu.ft.
  B. Different timbers may vary in weight from about 3 to 83 lbs./cu.ft.
  C. Variation in density may be caused by
    1. Difference in species.
    2. Rate of growth, and site conditions.
    3. Location from which a timber was taken within a single tree.
      a. Heaviest wood found at the base of the tree
      b. Wood closest to the pith is more dense than that near the bark in hardwoods - the reverse in softwoods

C. (cont'd)
   3. c. In diffuse porous hardwoods there is at first a slight increase in density as one moves from the pith to the outside of the tree, the a reversal to gradual decrease.

D. The practical significance of density in wood
   1. The best single criterion for strength (generalization)
      a. Because it is generally an indication of a higher perdentage of cell wall substance per unit volume.
      b. Lesser density is usually an indication there is a higher proportion of soft tissues (parenchyma cells) per unit volume and consequently more cells whihh have thin,weak walls.

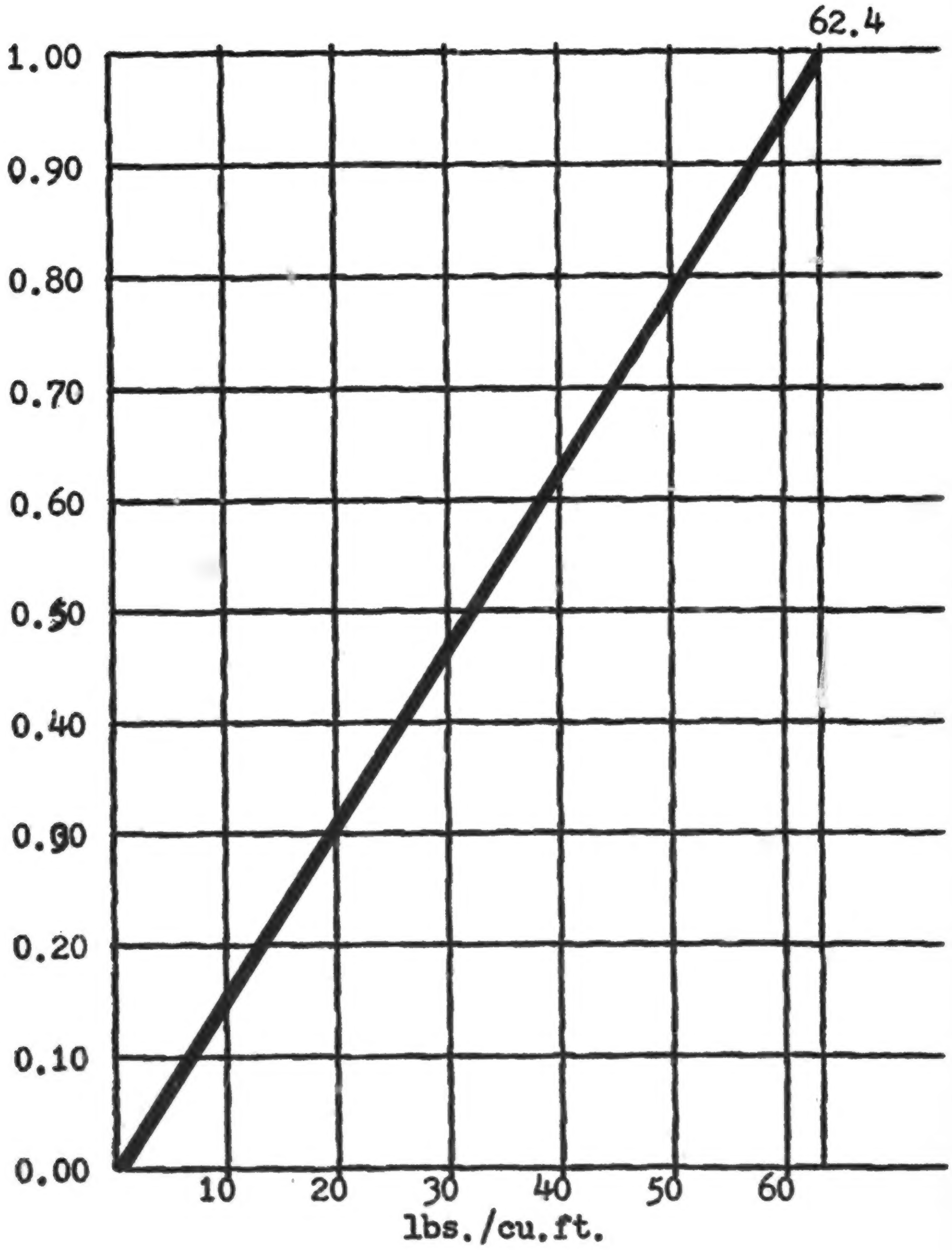


Fig. 1-Specific gravity and pounds per cubic foot conversion table *

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* Desch, H.E., Timber, Its Structure and Properties, p. 111

THE STRENGTH PROPERTIES OF WOOD

I. Definitions:
   A. Strength is the ability to resist external forces or loads
   B. Stresses external forces or loads which to tend to change the size and/or shape of a material.
      1. Stresses are expressed in load per unit area.
      2. The unit stresses are described in terms of lbs/sq.ft. or grams/sq. centimeter.
   C. Deformation or strain is the term used for change in size and/or shape.
   D. Proportional limit is that point at which wood no longer deforms proportional to the load applied.
   E. Fibre stress at proportional limit is the quantitative value of the stress applied at the proportional limit.
   F. Elasticity is demonstrated by a materials ability to return to its original size and/or shape after stress is withdrawn.
   G. Elastic limit is that point at which any further applied stress will result in permanent deformation.
   H. Permanent set is the term applied to permanent deformation.
   I. Failure or rupture occurs when the cohesive forces within the material is exceeded by the stress applied.
   J. Fibre stress at maximum load is the quantitative stress applied at time of rupture.
   K. Compressive stress is a force tending to crush a material.
      1. Compressive stress may be expressed in relation to wood fibre direction.
      2. When compressive stress is qualified regarding direction, it is either called compression on end grain or compression on edge grain.
   L. Tensile stress is a force tending to elongate the fibres in wood.
   M. Shearing stress is a force tending to slide one portion of a material over the other. It too is oriented in relation to grain direction, i.e., shear parallel to the grain or shear perpendicular to the grain.
      1. Shear perpendicular to the grain can never be measured accurately due to combined compressive stress, tensile stress and shear parallel to the grain. (see fig.1)
      2. Shear parallel to the grain can be determined more easily because the compression strength on end grain exceeds the cohesive nature of the wood along the length of the fibres.
   N. Flexibility is the ability to bend freely and return to original shape.
   O. Stiffness is the ability to resist bending.
   P. Modulus of elasticity is a measure of the relationship between stress and strain within the limit of proportionality.
   Q. Brittleness is the property of suffering little deformation without breaking. It does not imply weakness.
   R. Toughness is defined through combining three different criteria of measurement:
      1. Shock-resisting ability, tested by the drop of a special

(50 pound hammer)
weighted hammer. (In timber testing laboratories)

2. Work done to maximum load which is stress applied to cause rupture or failure.
3. Total work in bending provides an estimate of the ability of the material to sustain a considerable load after maximum load has been reached.

S. Hardness, like toughness is defined in more than one way:
  1. Resistance to cutting.
     a) Due to crystals or
     b) deposits of silica in storage tissue and interlocking fibres.
  2. Resistance to abrasion.
  3. Resistance to indentation - easiest to measure by a standard.

II. Assessment of Strength Properties

A. Much empirical knowledge exists regarding strength properties of some common species, i.e.;
  1. Oak as a structural material.
  2. Ash for toughness in tool handles, etc.
  3. Holly for hardness.

B. Much need for accurate comparison of timbers from different countries, or even different sides of a mountain range.
  1. Possible only through standard testing procedures.
  2. Most practical, time-wise, under laboratory conditions, though most valid under service conditions.
     a) Laboratory conditions give quick results.
     b) Service conditions actually subject test items to practical and accurate site conditions of usage.

C. Evaluations are based on stress measurements;
  1.

$$\frac{\text{Load}}{\text{Sectional area}}$$

  2.

strain measurements:

$$\frac{\text{Deformation}}{\text{Original length}}$$

D. Timber testing laboratories established by governments after 1914-1918 war years at:
  1. Princes Risborough, England.
  2. Ottawa, Montreal, and Vancouver, Canada.
  3. Forest Products Laboratory; Madison, Wisconsin.
  4. Melbourne, Australia
  5. Dehra Dun, India
  6. Sentul, Malaya

III. Methods of Determining The Strength Properties of Wood

A. Two alternative methods
   1. Service tests
   2. Laboratorg experiments } ---The advantages and disadvantages of these have been discussed.

B. Laboratory experiments conducted on small, clear specimens
   1. For comparative purposes, as an indication of strengths.
   2. Avoids influence of knots and other defects thus requiring the use of a reduction factor to obtain working stresses.

C. Laboratory tests on timber of structural size
   1. More nearly reproduce site conditions.
   2. More valid for they include such defects as knots and splits. --------COSTLY!

D. Full scale tests of commercially important trees are made on specimens within a species from more than one locality and may involve more than ten or fifteen trees to allow for variation between different trees within a species.
   A. Recently, it has been found important to test specimens taken from given environment that may have unique influence on growth rate or other characteristics.

IV. Strength Tests

A. Compression test
   1.. Perpendicular to the grain. (see fig.2)
      a) Specimens are 2"x2"x6" with two radial surfaces.
      b) Readings of deflection and load are taken simultaneously
      c) The stress computed is at fibre stress at proportional limit.
      d) Compression is over 2 square inches centrally located along length of test piece.
      e) Formula is:

$$\frac{\text{Load in pounds}}{\text{Bearing surface in sq. inches}}$$

      f) Values computed are of same order as in hardness test
      g) High values indicate woods suitable for use as sleepers, rollers, wedges, bearing blocks, bolted timbers.
   2. Parallel to the grain (see fig.3)
      a) Specimens are 2"x2"x8"
      b) Specimens are placed on end on a flat surfaced, hemispherical bearing.
      c) The load is applied through a plate contacting the full sectional area of the second end of the piece, parallel to the grain.
      d) During regular load increments, readings in deformation are made up to point of failure.
      e) Calculations made are in lbs/sq.in. at:
         (1) Maximum crushing strength,
         (2) Fibre stress at proportional limit,
         (3) Modulus of elasticity (in inch-lbs/cubic inch).
         (4) Work to elastic limit.

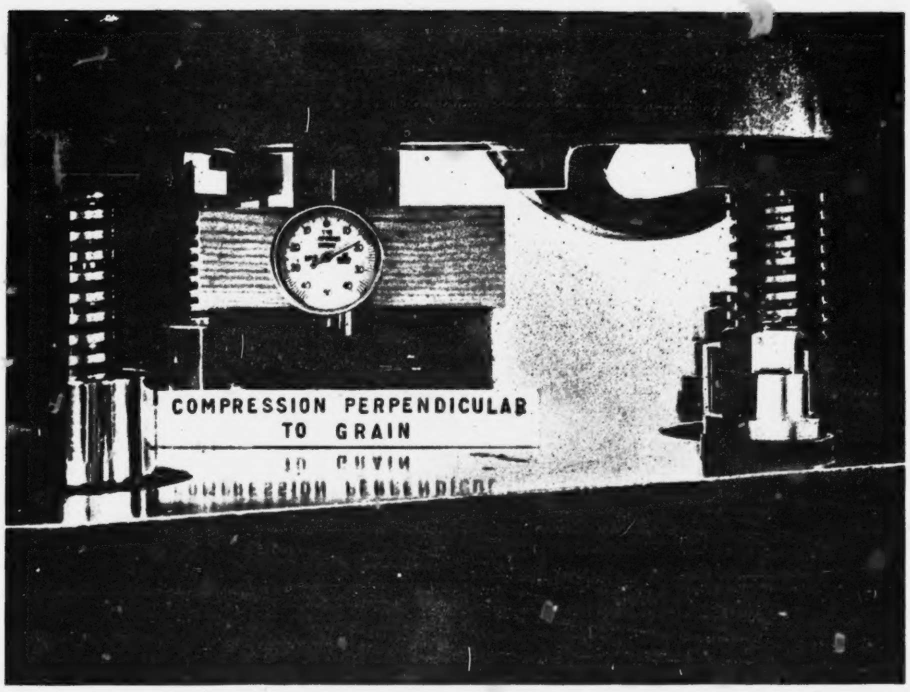
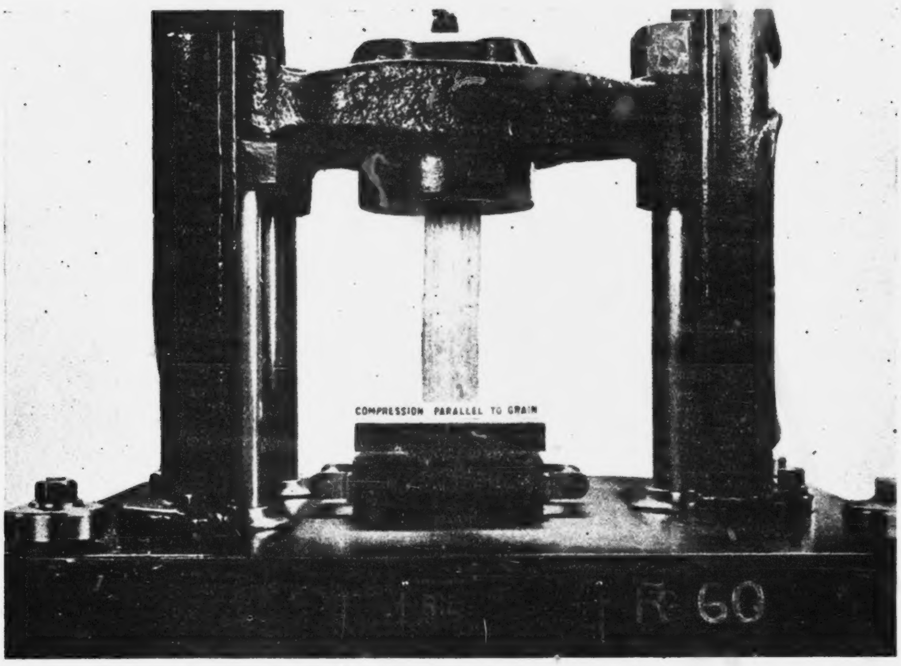

COMPRESSION PERPENDICULAR
TO GRAIN

FIG. 1


COMPRESSION PARALLEL TO GRAIN
R 60

Illustrating the testing machines, the test pieces, and method of applying the load in compression perpendicular and parallel to the grain

Photo by F.P.R.L., Princes Risborough

8

(5) Formulas:

$$\text{Modulus of elasticity} = \frac{\text{Ld. at Prop. Limit x Orig. length}}{\text{X-sect. in sq. ins. x total short. at Prop. Limit}}$$

$$\text{Work at Elastic Limit} = \frac{\text{Ld. at prop. limit x total short. at prop. limit}}{\text{2x volume of test sample in cu. ins.}}$$

(6) Members subjected to compression have high proportion of length in relation to their cross-section area.
  (a) Likely to fail in bending before full crushing force is applied.
  (b) Test samples consequently are of large cross-sectional area in relation to their length, to permit load to compression failure.
  (c) Compression test is considered best single criterion of the strength properties of a timber. (see fig. 3) A test procedure is included at the close of this chapter.

B. Shear Tests

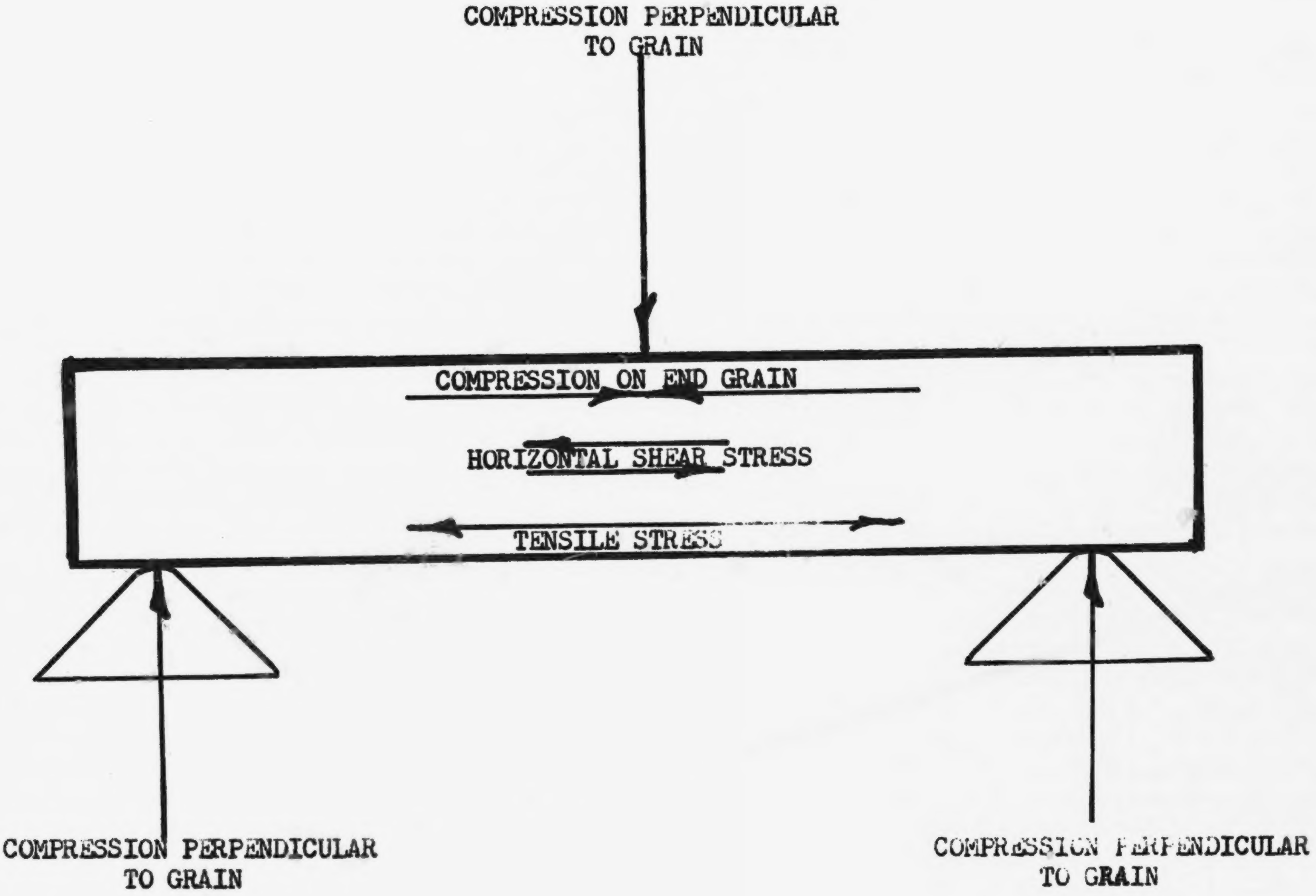
1. Shear perpendicular to grain is not measured because other forces contribute to failure. (see page 1, M. and fig. 1)
2. Shear parallel to the grain is measured at the point of complete failure.
3. Shearing strength with the grain is determined by the force required to shear off a projecting lip from a block of wood as illustrated in figure 4.
4. Horizontal shear is demonstrated in figure 5.
5. A shear test experiment with accompanying jigs is included at the end of this section.

C. Static Bending Tests

1. Designed to determine cross breaking strength or strength as a beam.
2. Specimens are typically 30" in length with a 2", square end.
3. The test piece is supported at points 28" on center and both ends are free to move.
4. The heart face of the board is toward the applied stress.
5. Load is applied at the middle of the span. (see fig. 6 & 7).
6. Readings of deflection and load are taken simultaneously with deflection incurred at .015" per minute.
7. Calculations made are for:
   a) Fibre stress at maximum load
      (1) Formula:

$$R = \frac{1.5\,P\,L}{bh^2}$$

R - fibre stress at maximum load (modulus of rupture)
P - load in pounds
L - length of span in inches
b - width of piece in inches
h - thickness of piece in inches


COMPRESSION PERPENDICULAR TO GRAIN
COMPRESSION ON END GRAIN
HORIZONTAL SHEAR STRESS
TENSILE STRESS
COMPRESSION PERPENDICULAR TO GRAIN
COMPRESSION PERPENDICULAR TO GRAIN

EDGE GRAIN SHEAR TEST (beam)
COMBINED STRESSES

b) Fibre stress at the limit of proportionality.

(1) Formula:

$$r = \frac{1.5\ P_1 L}{bh^2}$$

r=fibre stress at proportional limit in lbs/sq. ft.
P_1 = Load at the limit of proportionality in pounds.
L = Span in inches.
b = Width of test piece in inches.
h. = Thickness of test piece in inches

c) Modulus of Elasticity

(1) Formula:

$$E = \frac{P_1 L^3}{4\ Dbh^3}$$

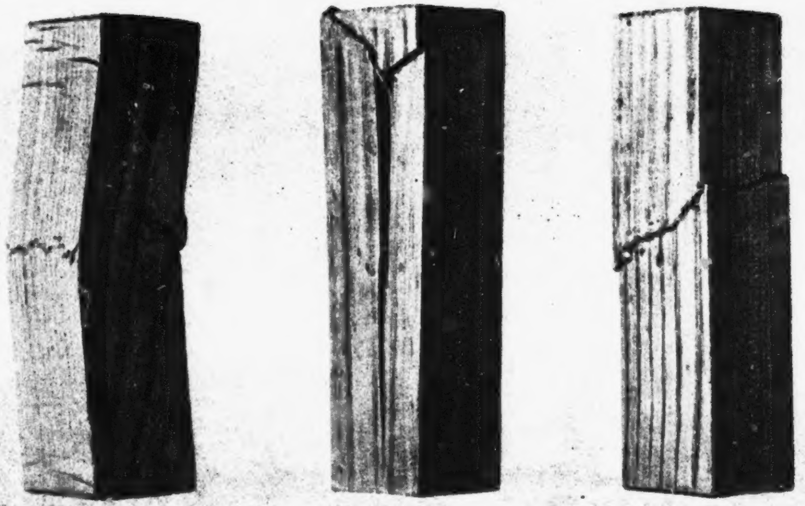
E = modulus of elasticity
D = Deflection in inches
P_1, L,b, and h are as before.

d) Hardness Tests

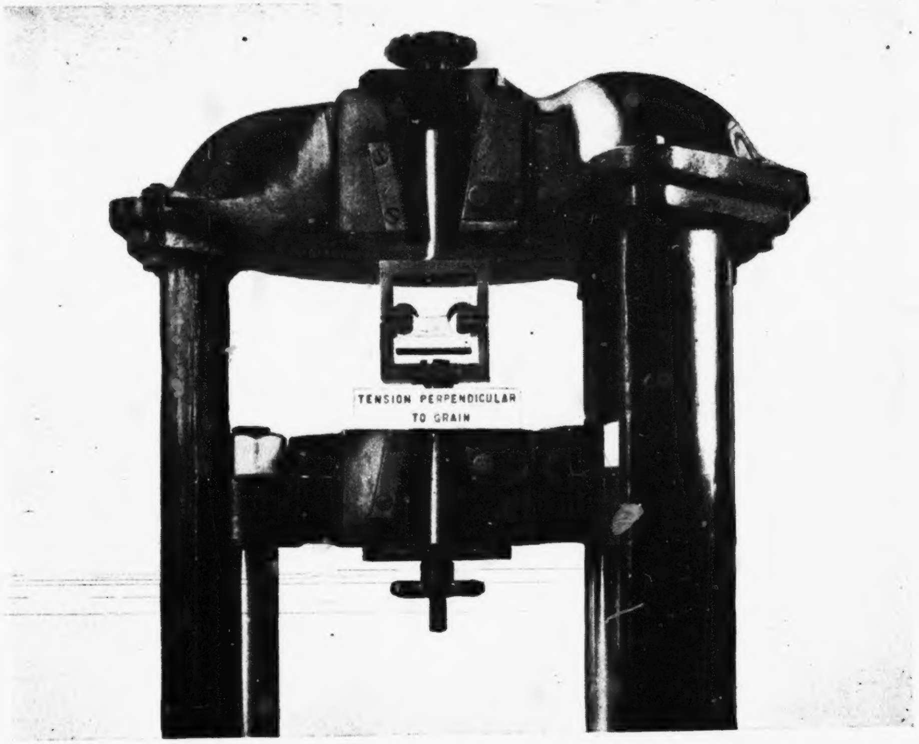
(1) Consists of imbedding a .444" steel ball or hemispherical rod .222" into the test piece.
(2) Tests are made on radial, tangential and transverse surfaces of test piece. (see figs.9 and 10)
(3) See experiment on hardness of wood.

e) Cleavability test

(1) Figure 11 illustrates test piece and apparatus used in cleavability test
(2) Specimens are cut so that half are radial and half are tangential.
(3) Some factors contributing to poor cleavability resistance are:
  (a)Radial cleavage:
    i) broad rays.
    ii) straight grained timbers.
  (b)Tangential cleavage:
    i) interlocked grain.
    ii) tangential series of resin canals.



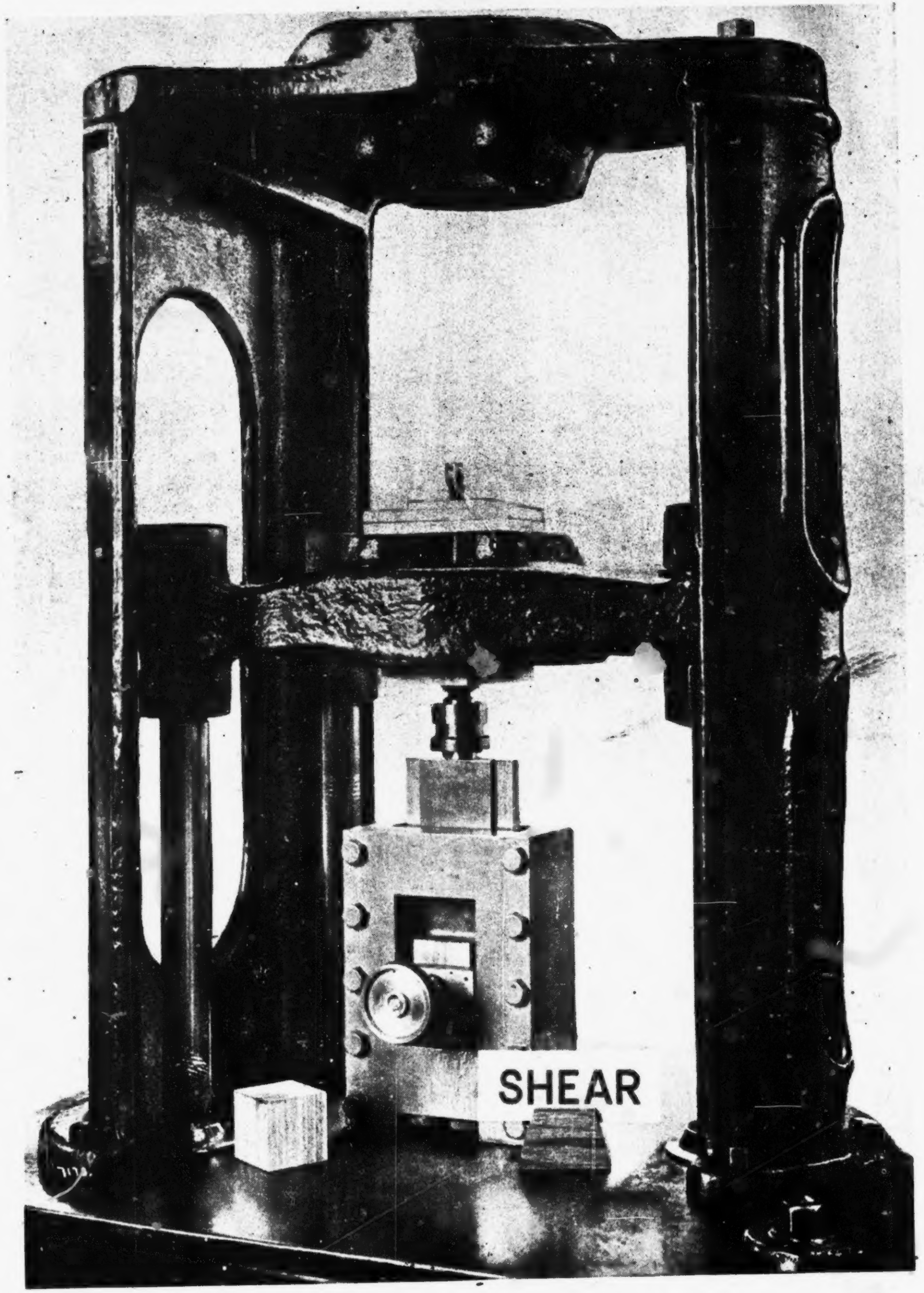
Types of failure in compression parallel to the grain



Illustrating the testing machine, the test piece, and method of applying the load in tension perpendicular to the grain

Photo by F.P.R.L., Princes Risborough

FIG. 2.



The load is applied over a portion of the cube illustrated on the base of the testing machine. Formerly the specimen was cut away, leaving a projecting lip and the load was applied to the stepped portion

Photo by F.P.R.L., Princes Risborough

V. The Influence of Microstructure of the Cell Walls on Strength Properties

A. Strength properties are roughly proportional to specific gravity.

B. In softwoods and ring-porous hardwoods, strength is governed by the proportion of late wood in the growth ring.

C. In softwoods and ring-porous hardwoods, slow grown specimens are below the average strength and specific gravity for the species.

D. Strength values vary in lumber from a single tree dependent upon which location it was milled from.

E. Environmental factors influencing growth sometimes produce timbers of more than average strength for a given specific gravity.

F. Abnormal tissues such as compression wood (softwoods) and tension wood (hardwoods) contribute to critical variations in strength properties
  1. Both have an extremely high rate of shrinkage from the green to dried state.
  2. Compression wood is heavy, dark and brittle.
  3. Tension wood is light in weight, light in color and fibrous in nature.

G. Wide variations in strength largely dependent upon the composition of the cell wall.
  1. Usually due to lignification factors.
  2. Lignification takes place largely in area of the secondary wall of fibre cells.
  3. Initial failure occurr primarily in the middle lamella or in parenchymatic tissues, (soft tissues) a special zone of weakness due to very thin cell walls.
  4. The composition of the cell walls is determined by growth conditions related to environmental temperatures, absence or presence of water, traces of certain mineral elements.
     a) There are optimum conditions under which each species will develop its best qualities.
     b) Trees of the same species growing on different sides of a mountain may have entirely different properties.

VI. The Influence of Moisture on the Strength Properties of Wood

A. Generally, the higher the moisture content, the less strength. (see table*)

---

* Garrat, G.A., The Mechanical Properties of Wood. John Wiley & Sons New York, 1931 p 133.

AVERAGE INCREASE (OR DECREASE) IN VALUE OF VARIOUS STRENGTH PROPERTIES EFFECTED BY DECREASING (OR INCREASING) MOISTURE CONTENT 1 PER CENT. WHEN AT ABOUT 12 PER CENT.[2]

Property	Per cent.
Static bending :	
Fibre stress at elastic limit	6
Modulus of rupture	4
Modulus of elasticity	2
Work to elastic limit	8
Work to maximum load	– 1
Impact bending :	
Fibre stress at elastic limit	4
Work to elastic limit	5
Height of drop of hammer causing complete failure	– 3
Compression parallel to grain :	
Fibre stress at elastic limit	5
Crushing strength	4
Compression perpendicular with grain :	
Fibre stress at elastic limit	6
Hardness — end	3
Hardness — side	1
Shearing strength parallel with grain	4
Tension perpendicular to grain	1

Fig. 5

VII. The Influence of Defects on Strength

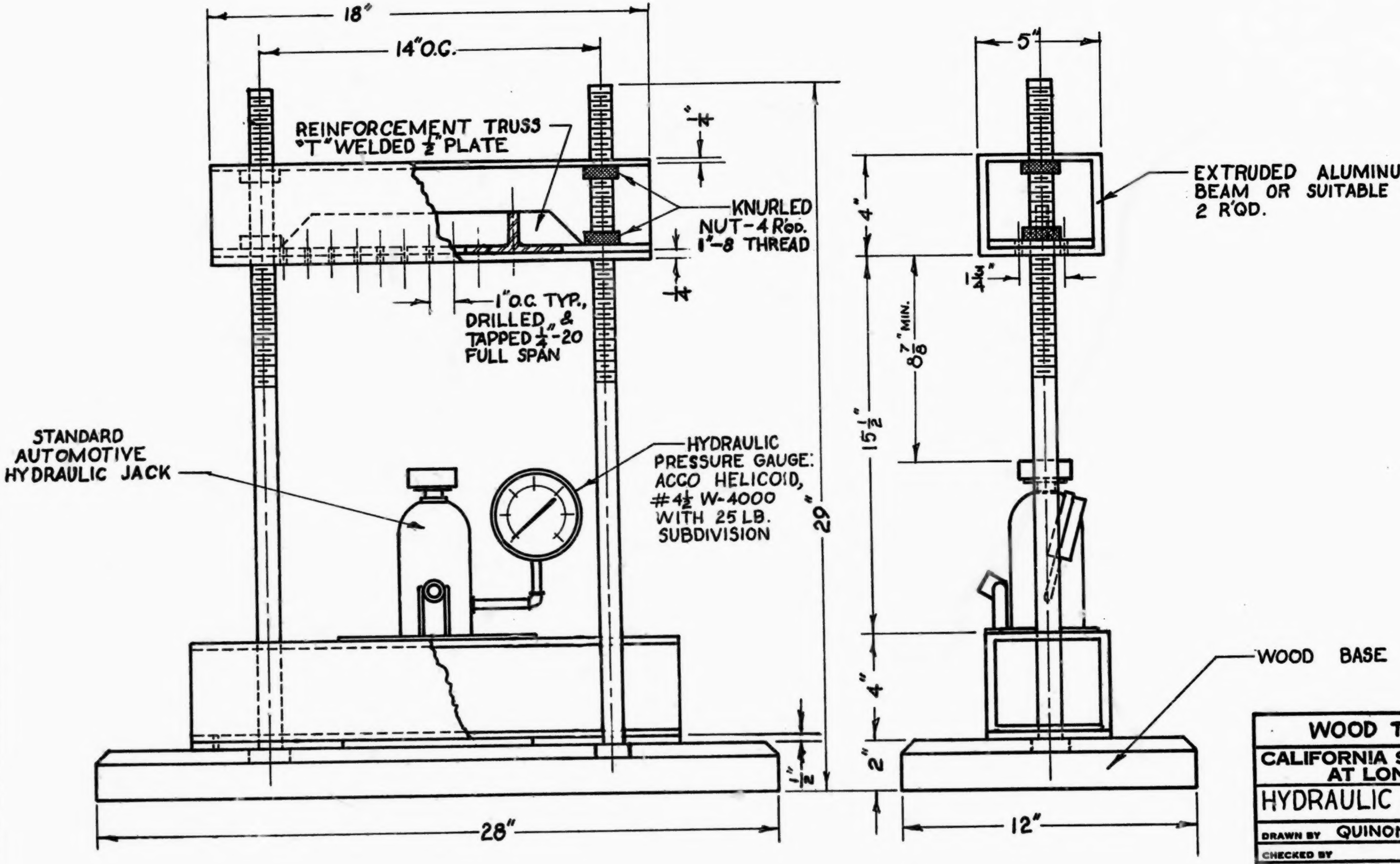
A. Defects fall into two categories covered in the section on "Natural Defects" and "Seasoning Degrade". Briefly:
   1. Grain irregularities.
   2. Splits and checks, shakes.
   3. Presence of rot.
   4. Abnormalities in anatomical structure:
      a) Frost rings and checks.
      b) Compression wood
      c) Tension wood
      d) Abnormal concentrations of soft tissues (parenchyma)
   4. Knots.
   5. Bark pockets.
   6. Pitch pockets, streaks and gum veins.
   7. Latex canals. 8. Cross grain.

B. The position of a defect in a timber is the most critical factor accompanying its presence.
   1. Defects near an edge of timber are serious in bending stress.
   2. Knots have little effect on compression strength parallel to the grain, and degree of influence is governed by size.
   3. Shakes, splits and pitch streaks are critical factors in shear parallel to the grain.
   4. Presence of compression wood and the resultant "spungy heart" (checks acress the grain) which occur in seasoning have critical effect on bending strength, shock resistance.
   5. More critical than the presence of a knot is the cross grain around a knot. The further a knot is away from support, the greater the decrease in strength in the member.

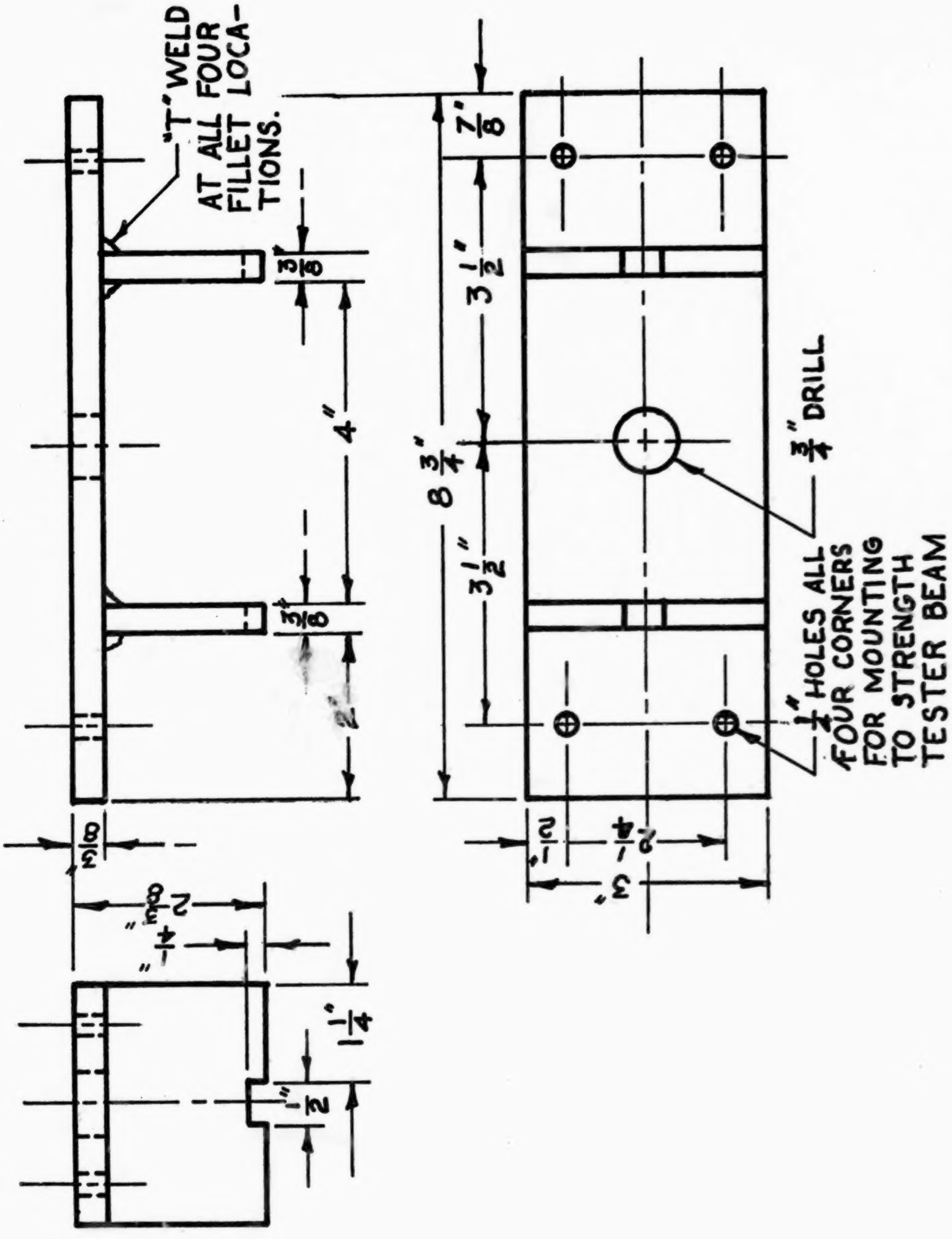
C. Reduction factors employed to compensate for prsence of defects.
   1. Based on empirical knowledge, often called "Fudge Factors".
   2. Different factors used dependent on condition of usage.*
      a) In Bending
         (1) 1/6th in dry places, under cover.
         (2) 1/7th outside, but not in contact with the soil.
         (3) 1/8th in wet places.
             (based on figures for green lumber)
      b) In compression parallel to the grain.
         (1) 1/4th in dry places, under cover.
         (2) 1/4th to 1/5th, outside, not in contact with the soil.
         (3) 1/5th in wet places.
             (based on figures for green timber)
      c) In shear
         (1) 1/10th of the average of the figures for radial and tangential stresses.
      d) In side or edge grain compression
         (1) 1/2.25 of the figure for the compressive strength perpendicular to the grain at the limit of proportionality.

---

* Desch, H.E., Timber, its Structure and Properties. McMillan & Co., New York, 1963. P.138.


18"
14"O.C.
REINFORCEMENT TRUSS "T" WELDED ½" PLATE
¼"
KNURLED NUT-4 R'QD. 1"-8 THREAD
¼"
1"O.C. TYP., DRILLED & TAPPED ¼"-20 FULL SPAN
STANDARD AUTOMOTIVE HYDRAULIC JACK
HYDRAULIC PRESSURE GAUGE: ACCO HELICOID, #4½ W-4000 WITH 25 LB. SUBDIVISION
29"
1½"
28"
5"
EXTRUDED ALUMINUM BOX BEAM OR SUITABLE SUBSTITUTE, 2 R'QD.
4"
1¾"
8⅞" MIN.
15½"
4"
2"
WOOD BASE
12"

WOOD TECHNOLOGY	
CALIFORNIA STATE COLLEGE AT LONG BEACH	
HYDRAULIC STRESS TESTER	
DRAWN BY QUINONES	COURSE IA-313
CHECKED BY	DWG NO 2
APPROVED BY	
DATE	
SCALE ¼" = 1"	SHEET OF


"T" WELD AT ALL FOUR FILLET LOCATIONS.
3/8"
4"
3/8"
2"
3/8"
2 3/8"
1/4"
1 1/4"
1/2"
7/8"
3 1/2"
8 3/4"
3 1/2"
3/4" DRILL
1/4" HOLES ALL FOUR CORNERS FOR MOUNTING TO STRENGTH TESTER BEAM
1/2"
2 1/4"
3"

WOOD TECHNOLOGY

CALIFORNIA STATE COLLEGE
AT LONG BEACH

TENSILE STRESS JIG

DRAWN BY QUINONES
COURSE
CHECKED BY
APPROVED BY
DATE
DWG NO 2
SCALE 1/2" = 1"
SHEET 2 OF 3

California State College
Long Beach

Hardness of Wood

Purpose: To develop an understanding of the term "hardness" and its many ramifications in design and construction.

Apparatus required:

Hardness evaluator
Hydraulic press with gauge
Samples of 10 different woods (1x2x2)
Drawing paper
Colored pencils

Experiment:

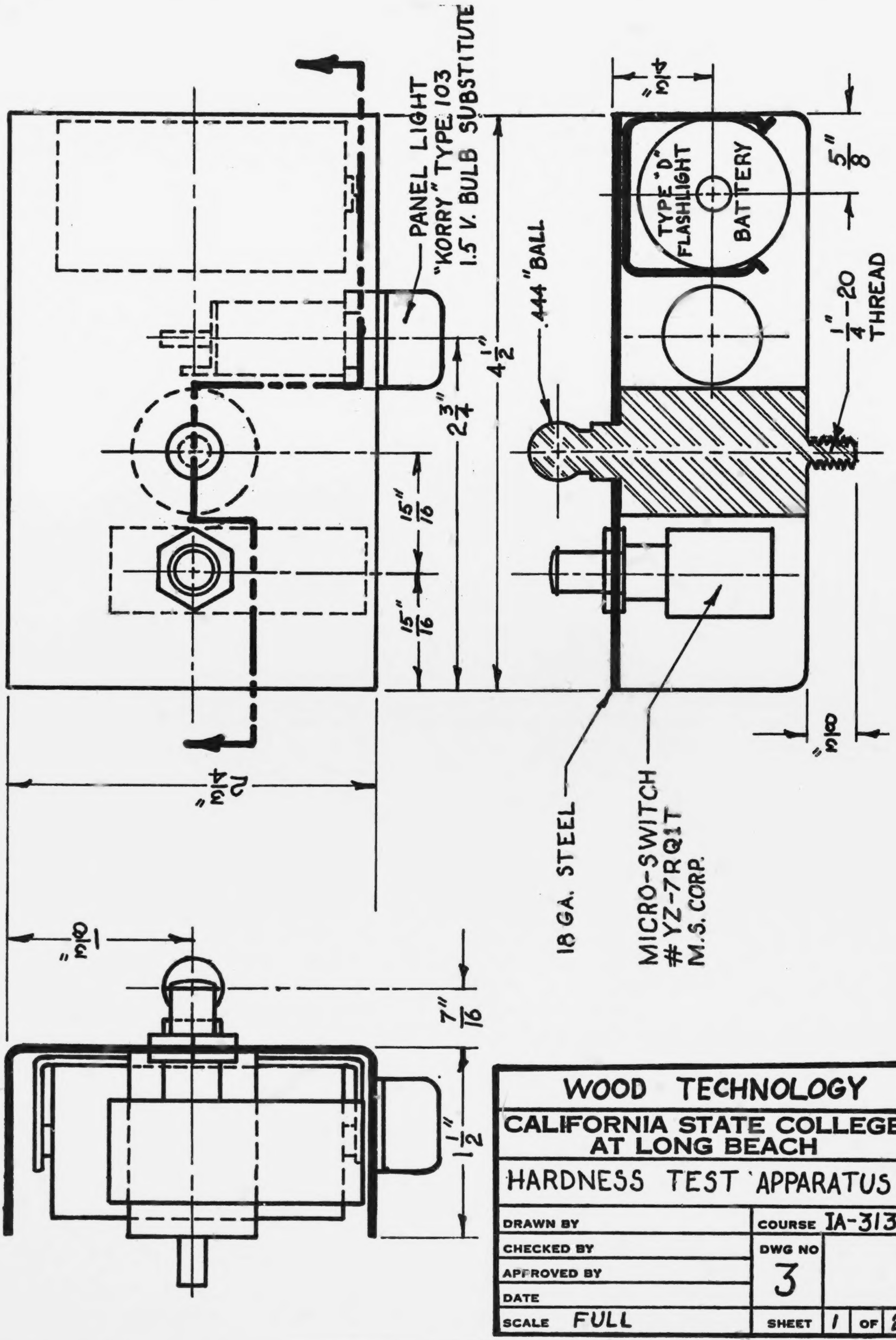
1. Properly identify the wood samples
2. Mount the hardness evaluator on the hydraulic press
3. Insert the wood sample into the sample holder
4. Bring the hardness evaluator up within range of the wood sample and in a position where the indicator light is visible
5. Pump the hydraulic press until the light is on and record the gauge reading
6. Complete this process for both the end-grain and side-grain surfaces on all ten samples
7. Rank the woods from soft to hard and develop a descriptive bar graph to compare the results.

Questions:

1. What is meant by the term "hardness of wood"?
2. How is the hardness of wood evaluated?
3. What is the relationship between the moisture content and the hardness of wood?
4. What is the relationship between hardness and resiliency?
5. Why is the study of hardness of wood an important phase of wood technology?

References:

Desch, H.E., Timber, Its Structure and Properties, MacMillan 1962, 3rd edition (corrected)

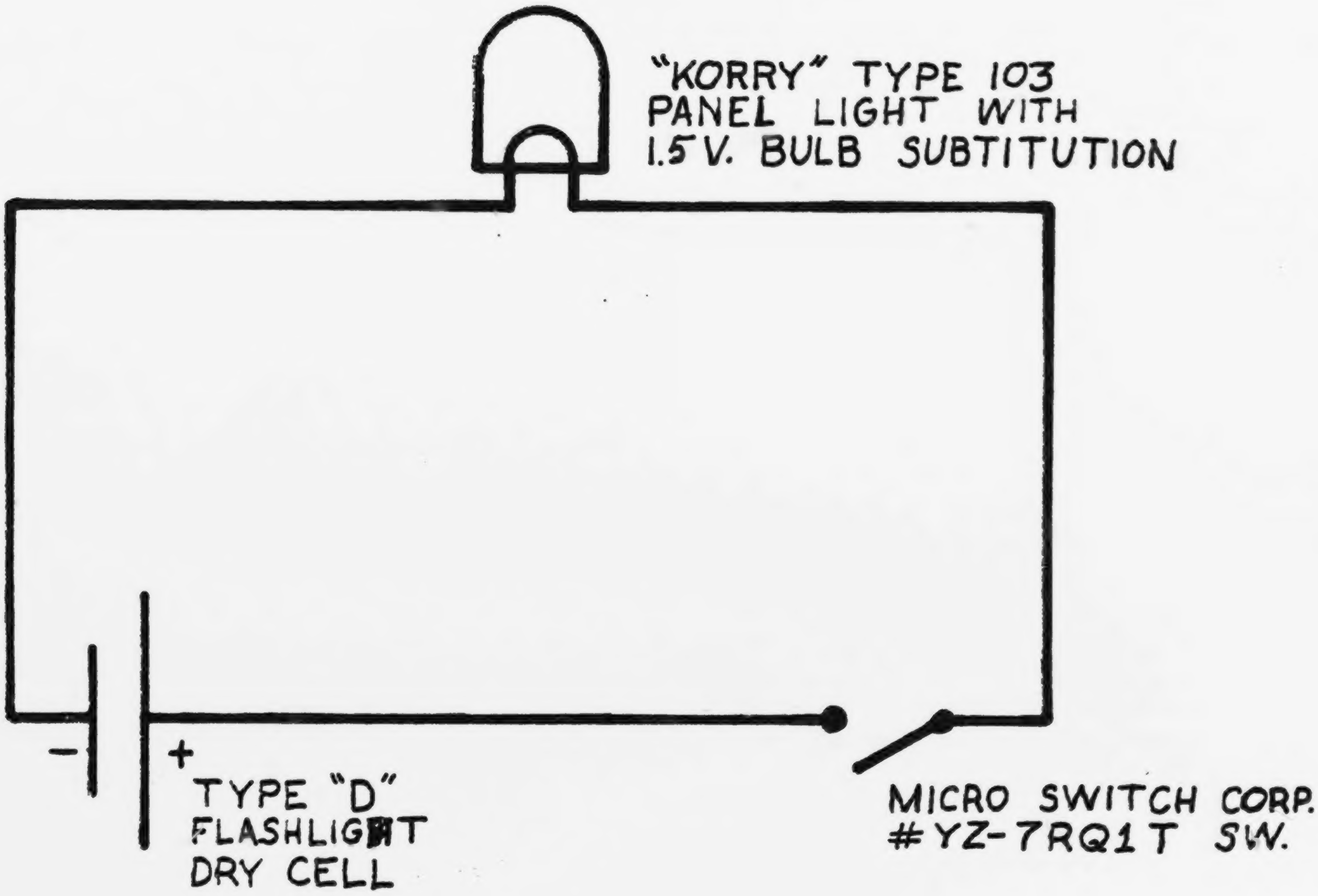

PANEL LIGHT
"KORRY" TYPE 103
1.5 V. BULB SUBSTITUTE
.444" BALL
TYPE "D" FLASHLIGHT
BATTERY
3/4"
5/8
1/4"-20 THREAD
4 1/2"
2 3/4"
15/16"
15/16"
3/8"
5 3/4"
18 GA. STEEL
MICRO-SWITCH
# YZ-7RQ1T
M.S. CORP.
1 3/8"
7/16"
1 1/2"

WOOD TECHNOLOGY

CALIFORNIA STATE COLLEGE
AT LONG BEACH

HARDNESS TEST APPARATUS

DRAWN BY	COURSE IA-313		
CHECKED BY	DWG NO 3		
APPROVED BY			
DATE			
SCALE FULL	SHEET	1	OF 2


"KORRY" TYPE 103
PANEL LIGHT WITH
1.5V. BULB SUBTITUTION
−
+
TYPE "D"
FLASHLIGHT
DRY CELL
MICRO SWITCH CORP.
#YZ-7RQ1T SW.

WOOD TECHNOLOGY			
CALIFORNIA STATE COLLEGE AT LONG BEACH			
WIRING DIAGRAM	HARDNESS TESTER		
DRAWN BY	COURSE IA-313		
CHECKED BY	DWG NO		
APPROVED BY	3		
DATE			
SCALE	SHEET	2 OF	2

California State College
Long Beach
Wood Technology
Anisotropic Properties of Wood

Purpose: To exhibit the variation in the physical properties of wood when tested along major directional axes.

Apparatus required:

Hydraulic press
Strength evaluation jigs
8 Transverse grain mahogany test pieces (1/2" sq. x 8" long)
8 Tangential grain mahogany test pieces (1/2" sq. x 8" long)
Graph materials

Experiment:

I. Compression test

1. Mount the strength evaluation jigs on the hydraulic press.
2. Insert 4 of the transvers and 4 of the tangential test pieces in the holes provided in the upper and lower parts of the evaluation jigs and apply breaking force.
3. Record the force required to break each piece.

II. 1. Locate the remaining samples in the notches on the top section of the evaluation jig and bring the hydraulic ram up to hold them in position.
2. Apply breaking force to each of the samples.
3. Record the data.

III. Develop a descriptive illustration of your own design that will asses the strength of the various sections in both the compression and shear tests.

Questions:

1. What are the implications of this experiment to the design and development of Industrial arts projects?
2. Why is wood stronger in one direction than it is in another?
3. What is a tangential section?
4. What is a radial section?
5. What is a transverse section?

TESTING THE SHEARING STRENGTH OF WOOD

Objective:

The purpose of this experiment is to gain an understanding of what "shearing strength" is, its relationship to the testing of small clear samples in the laboratory, and the applications of small sample testing.

Apparatus Required:

Hydraulic press with gauge

Shear Testing Jig

10 samples of different woods (see fig. 2 for size).

10 samples of the same woods that have been soaked
in water for 2 days (see fig. 2 for size).

Graph materials

NOTE:

If the hydraulic press available for the testing doesn't have enough force for this standard sized sample, then the samples can be modified. This can be done by making a saw cut parallel with the grain and in line with the back of the protruding lip. This will reduce the cross-sectional area and, therefore, will reduce the shearing strength of the sample, but because this experiment is used for comparative purposes only, it won't affect the experiment results any if all of the samples to be tested are cut to the same depth.

Procedures:

1) Properly identify the 10 different wood samples.
2) Mount the shear testing jig (fig. 6) on the hydraulic press. Be sure it is mounted in the correct position.
3) Insert the 10 dry samples (see fig. 5) one at a time, into the press and apply enough force to shear the samples in half. Record this force on your data sheet.
4) Insert the 10 soaked samples, one at a time and record the force required in the same manner as above.
5) After you have completed the testing of the samples, compare your results with the statistics given in the wood handbook table 12 (column 13) assume your soaked samples to be green timber. Include these statistics in your data sheet.
6) Rank the woods according to their shearing strength and make a bar graph to show the relationship between the different woods and the difference between the dry and wet samples.

Experiment Results:

1) Why is shear strength only tested parallel to the grain?

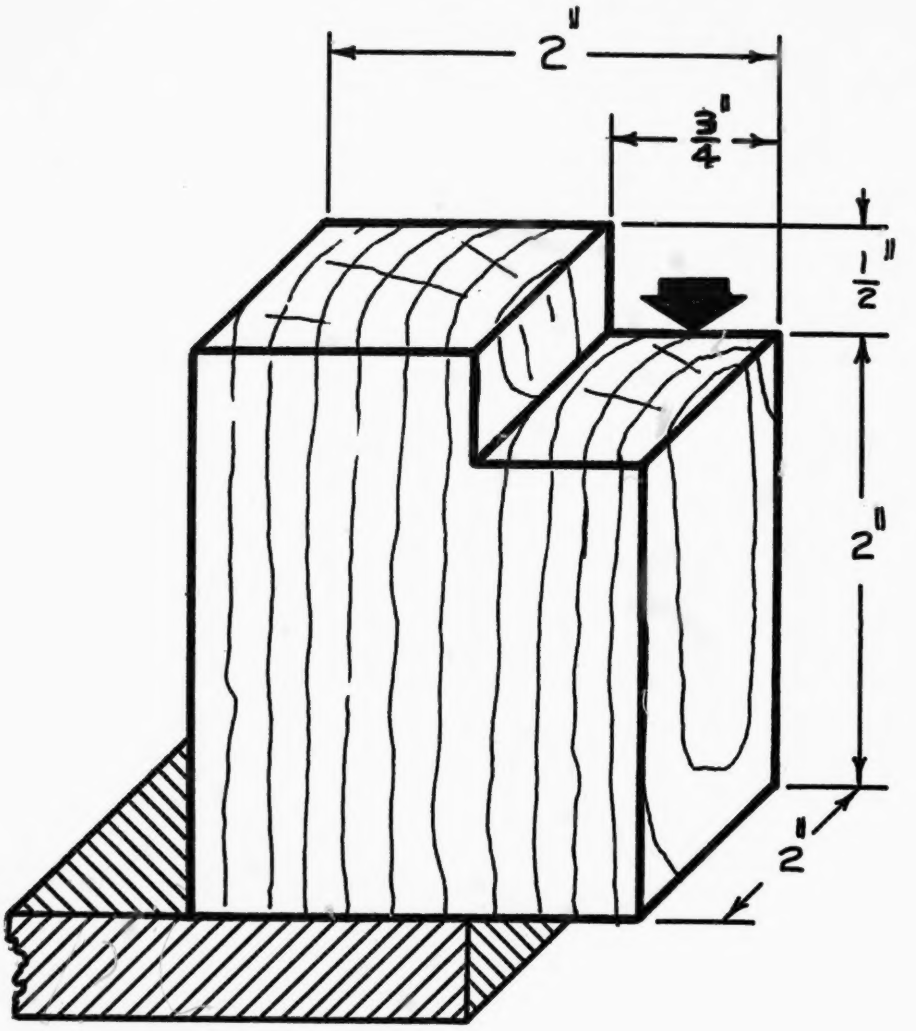


Fig. 4. - Wood specimen for shear test along the grain.

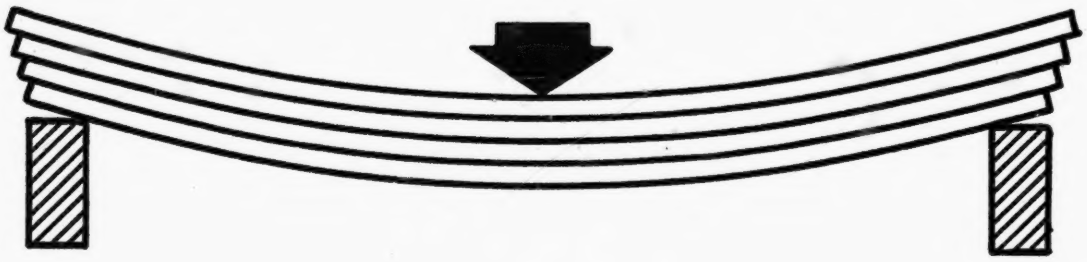


Fig. 5. - Horizontal shear between boards laid flat and bent as a beam.

2) What is a good example of shear failure in joint construction?

3) What is the relationship between moisture content and shear strength?

4) What seasoning defects cause the most failure in shearing strength? Why are these defects more common in the radial plane than in the tangential plane?

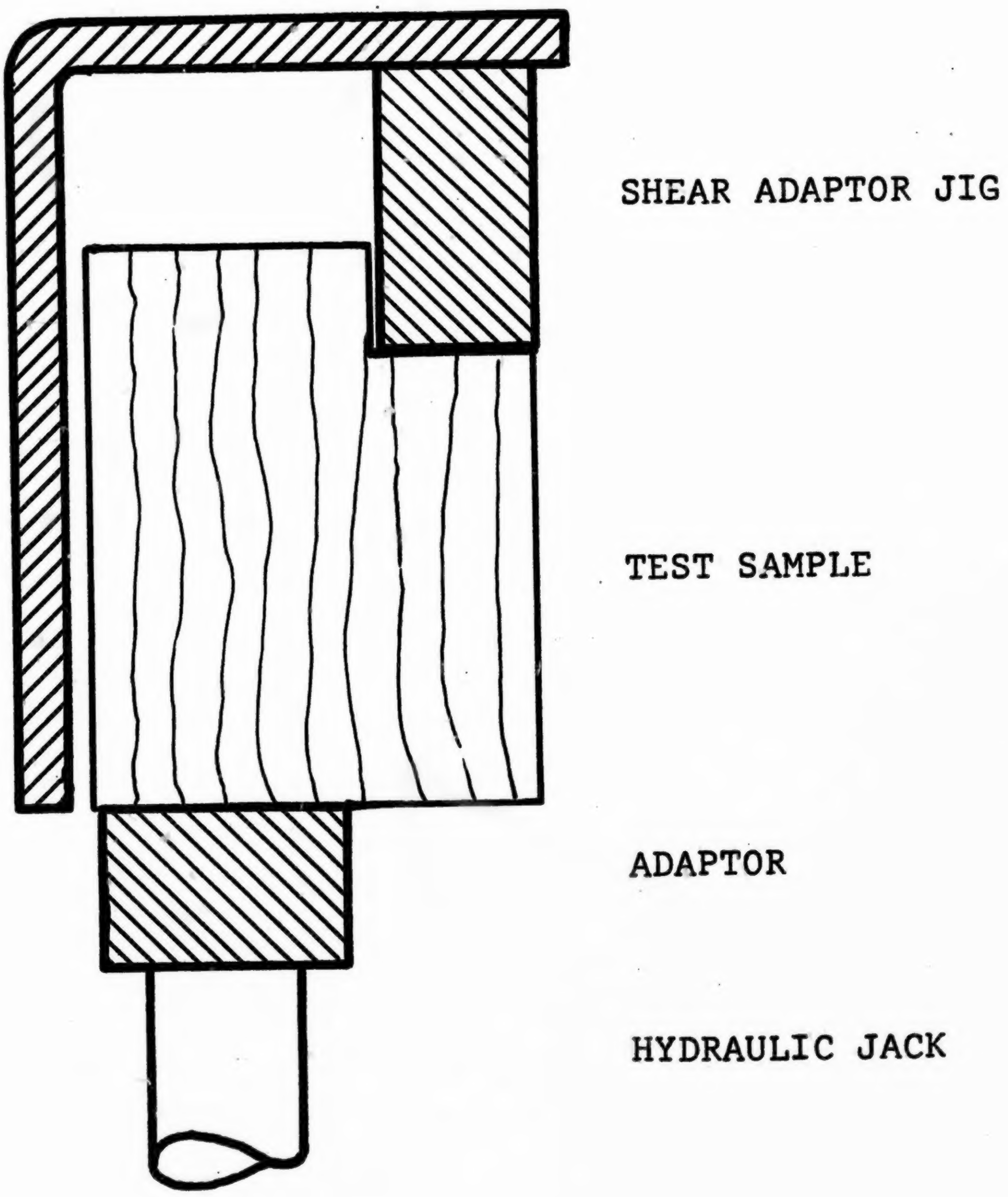
5) What is the biggest advantage of the testing of small clear samples?

6) Why are correction factors applied to the data obtained from testing small clear specimens?

7) Why is an understanding of strength properties of wood important to an industrial arts student?

DATA SHEET:

Specimen	Shear Strength (P.S.I.) (Dry Samples)		Shear Strength (P.S.I.) (Wet Samples)	
	Your Data	Books Data	Your Data	Books Data
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				



SHEAR ADAPTOR JIG
TEST SAMPLE
ADAPTOR
HYDRAULIC JACK

Fig. 5 - Mounting a shear test sample in the hydraulic press.

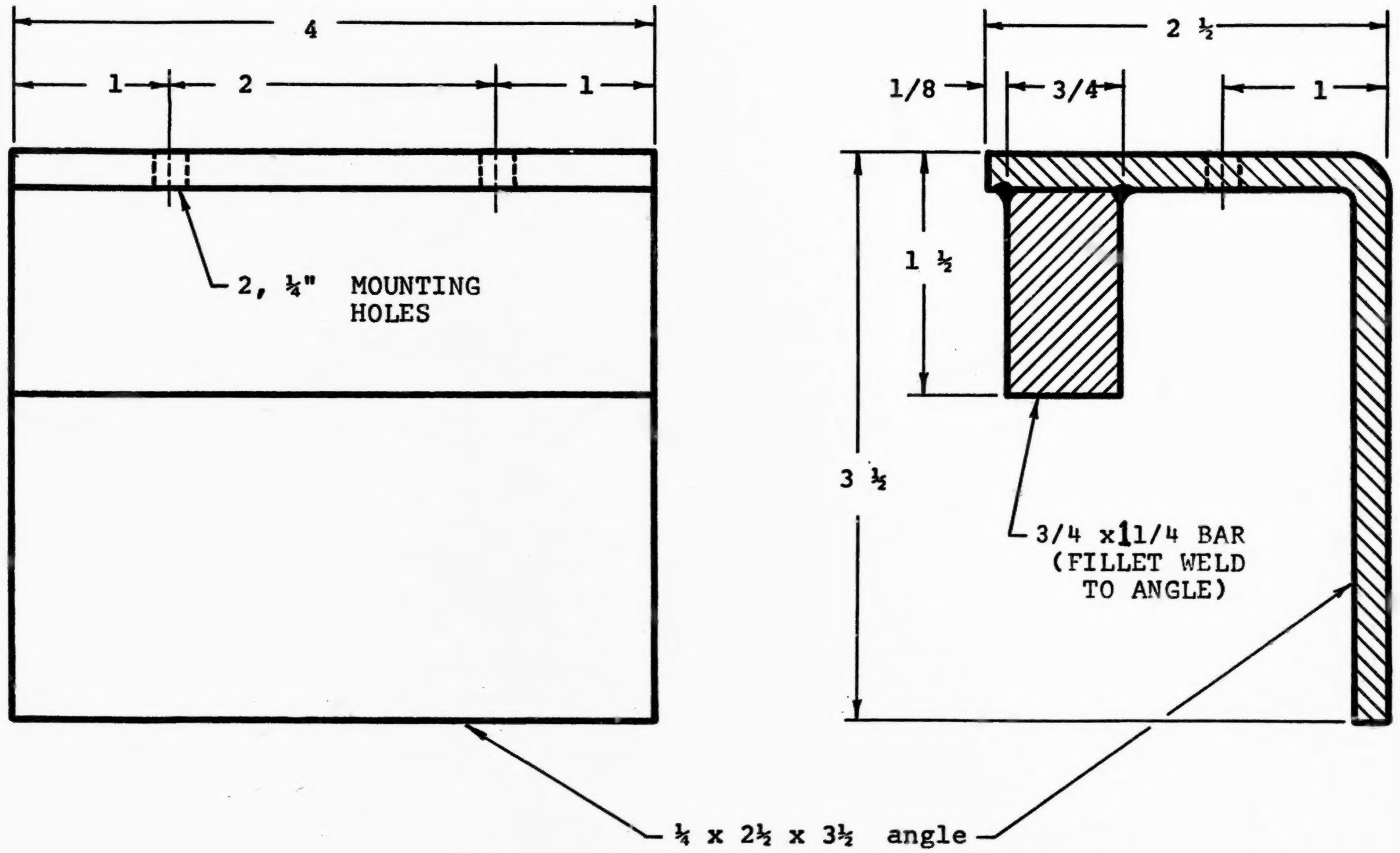

4
1
2
1
2, ¼" MOUNTING HOLES
2 ½
1/8
3/4
1
1 ½
3 ½
3/4 x 1 1/4 BAR (FILLET WELD TO ANGLE)
¼ x 2½ x 3½ angle

Fig. 6. - Plans for a shear testing adaptor

BIBLIOGRAPHY

Desch, H.E., Timber - Its Structures and Properties, New York, Mac Millan, 1962.

Forest Products Laboratory, U.S. Government Printing Office, Wood Handbook, Agriculture Handbook No. 72, 1955.

Koehler, Arthur, The Properties and Uses of Wood, Mc Graw Hill Book Co. New York, 1924.

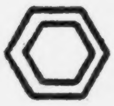
Yokobori, Takeo, The Strength, Fracture, and Fatigue of Materials, 1964.

DENSITY

A Physical Property of Wood

Wood is a cellular material -

Cell walls represent wood framework.

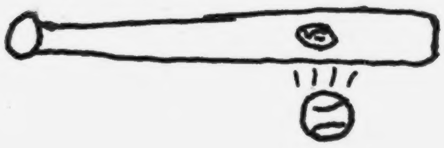
Softwood cells - Tracheids - 

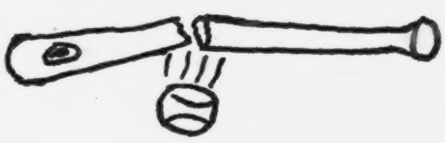
Hardwood cells

Wood Fibers -

Vessels or Pores -

Wood weight when dry is an index of the amount of cell-wall substance.





Wood substance a reliable indicator of strength characteristics.

Density also affects the following:

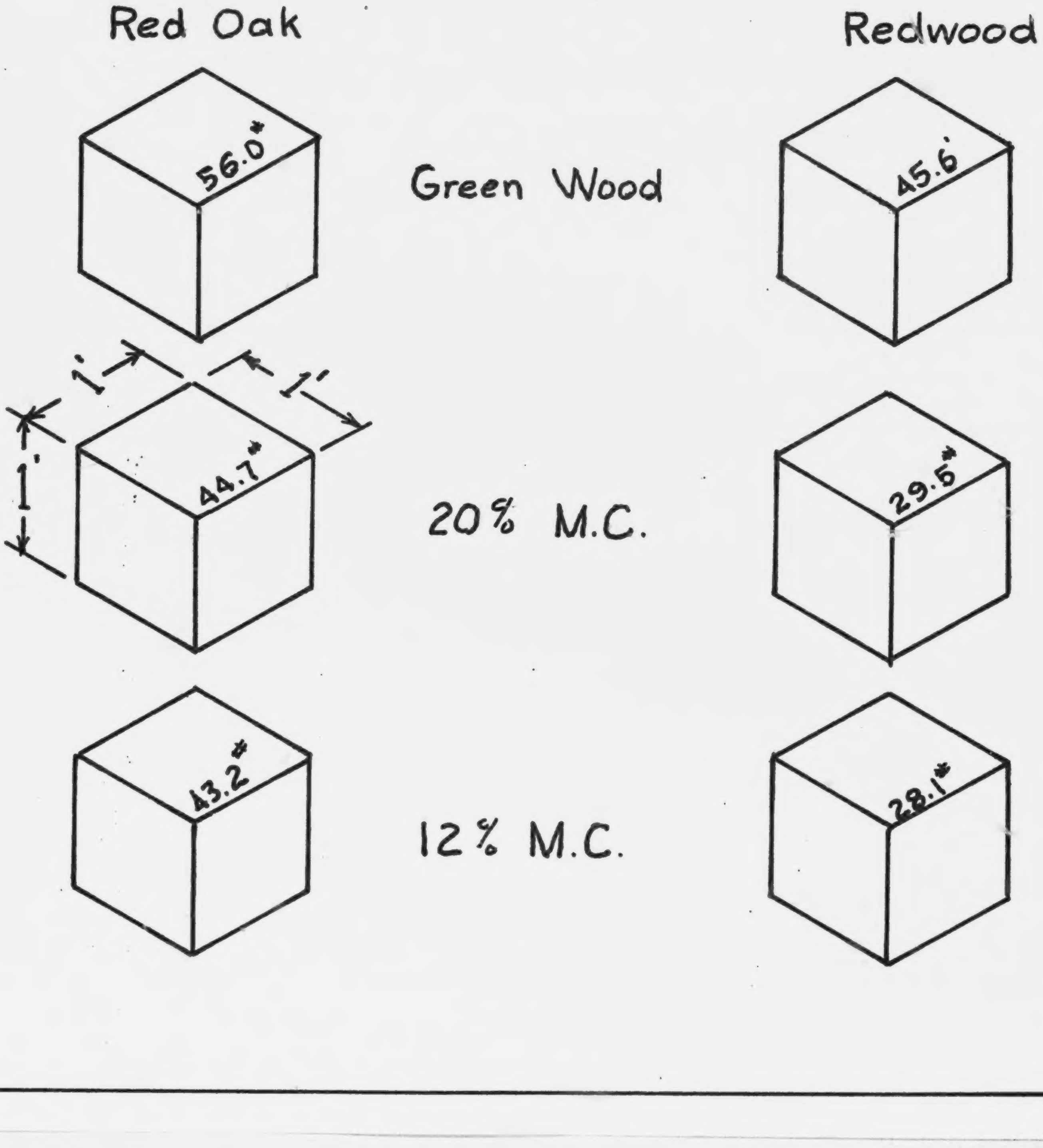
1. Wood working and finishing characteristics.
2. The extent of dimensional change with changes of moisture below fiber saturation point.

Density plays an important part in determining the utility of a given wood or a given piece.

DENSITY
AND
MOISTURE CONTENT

DENSITY: The mass or weight of any substance per unit volume.

Effect of moisture content (M.C.) on density.

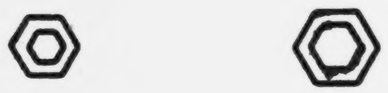

Red Oak
Redwood
56.0#
Green Wood
45.6#
1'
1'
1'
44.7#
20% M.C.
29.5#
43.2#
12% M.C.
28.1#

SPECIFIC GRAVITY

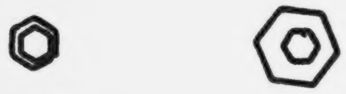
WOOD

Specific Gravity is dependent on:

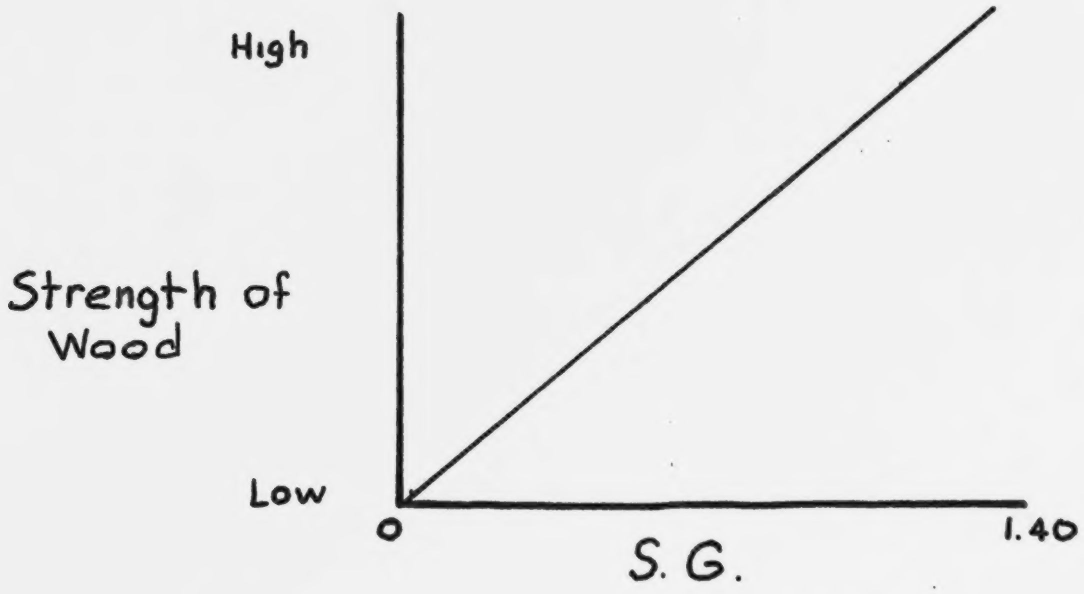
1. The size of cells.



2. The thickness of cell walls.



3. The interrelationship of number of various kinds of cells as related to size (1) and wall thickness (2).



SPECIFIC GRAVITY

WOOD

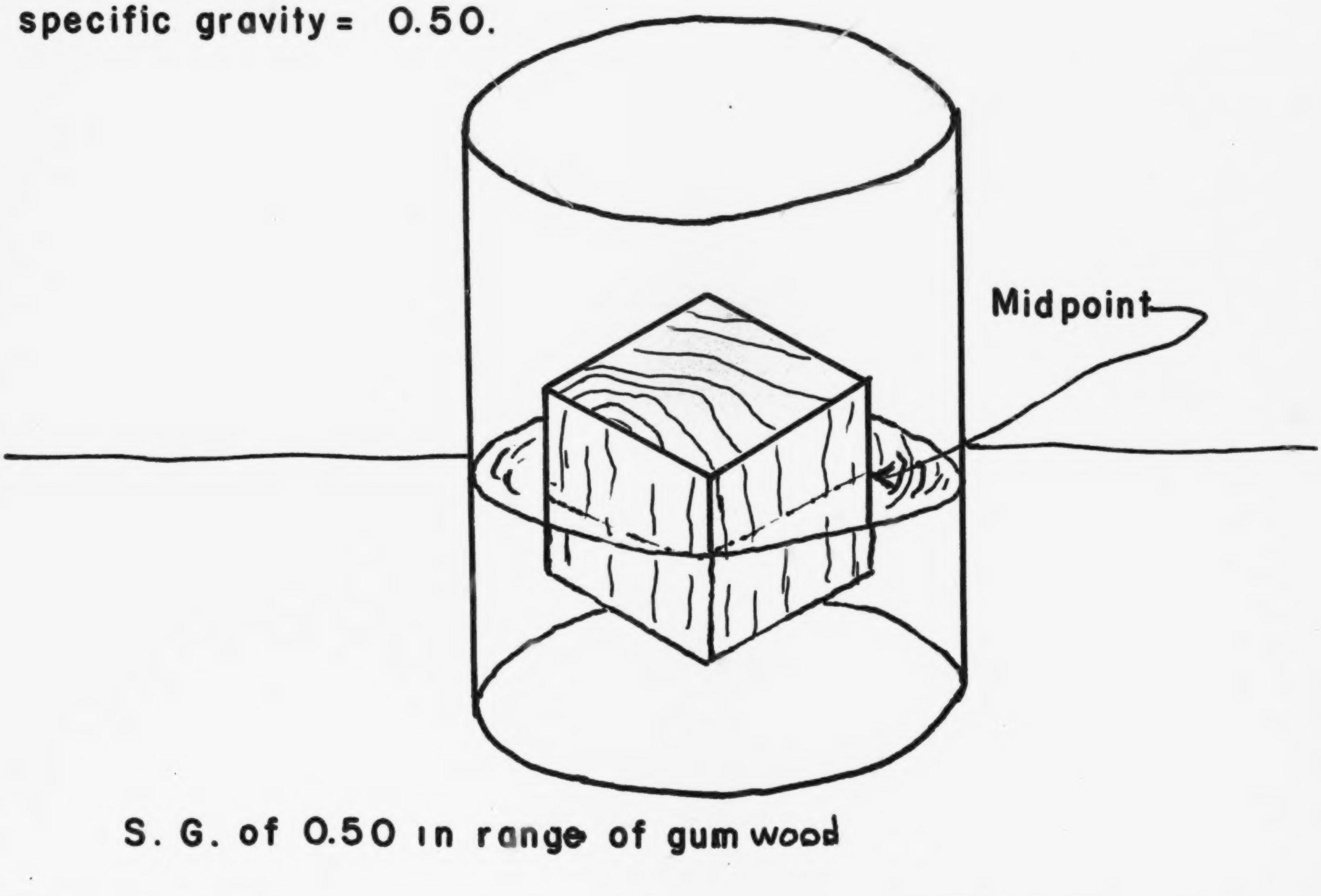
Defined:

Is the ratio of the density of a material to the density of water.

Water weighs- 62.4 pounds per cubic foot

$$\text{Specific Gravity} = \frac{\text{Wt. ovendry sample wood}}{\text{Wt. of equal volume of water}}$$

Example: If water line is exactly at mid point specific gravity = 0.50.

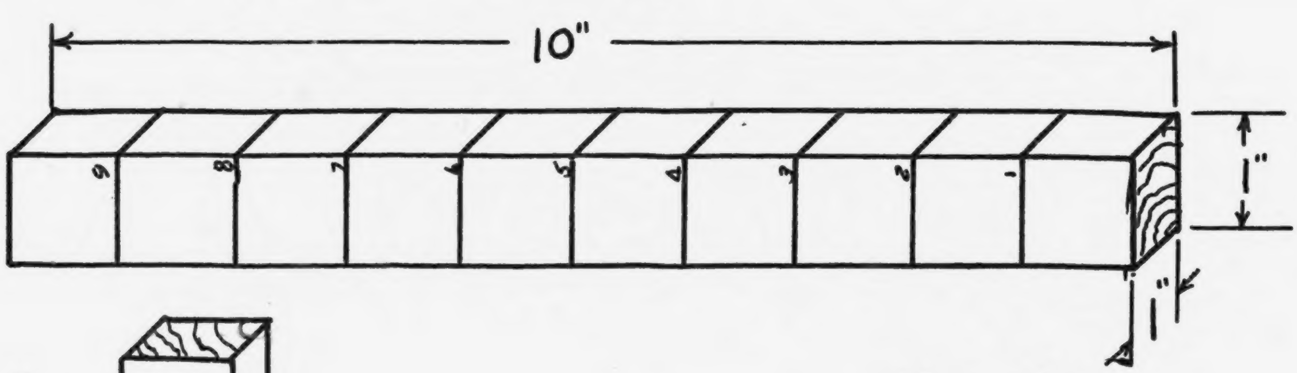


S. G. of 0.50 in range of gum wood

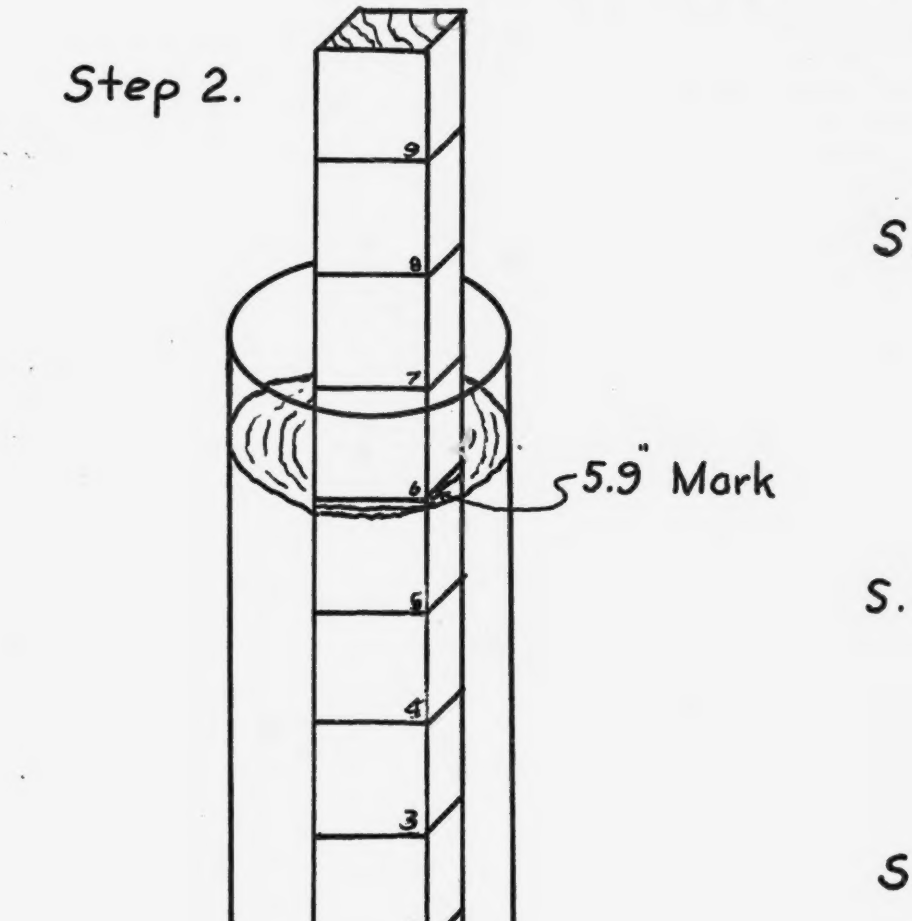
SPECIFIC GRAVITY
WOOD

The Rapid Flotation Method
An Approximation

Step 1. Wood Sample - Oven Dry


10"
9
8
7
6
5
4
3
2
1
1"
1"

Step 2.


9
8
7
6
5.9" Mark
5
4
3
2
1

Step 3

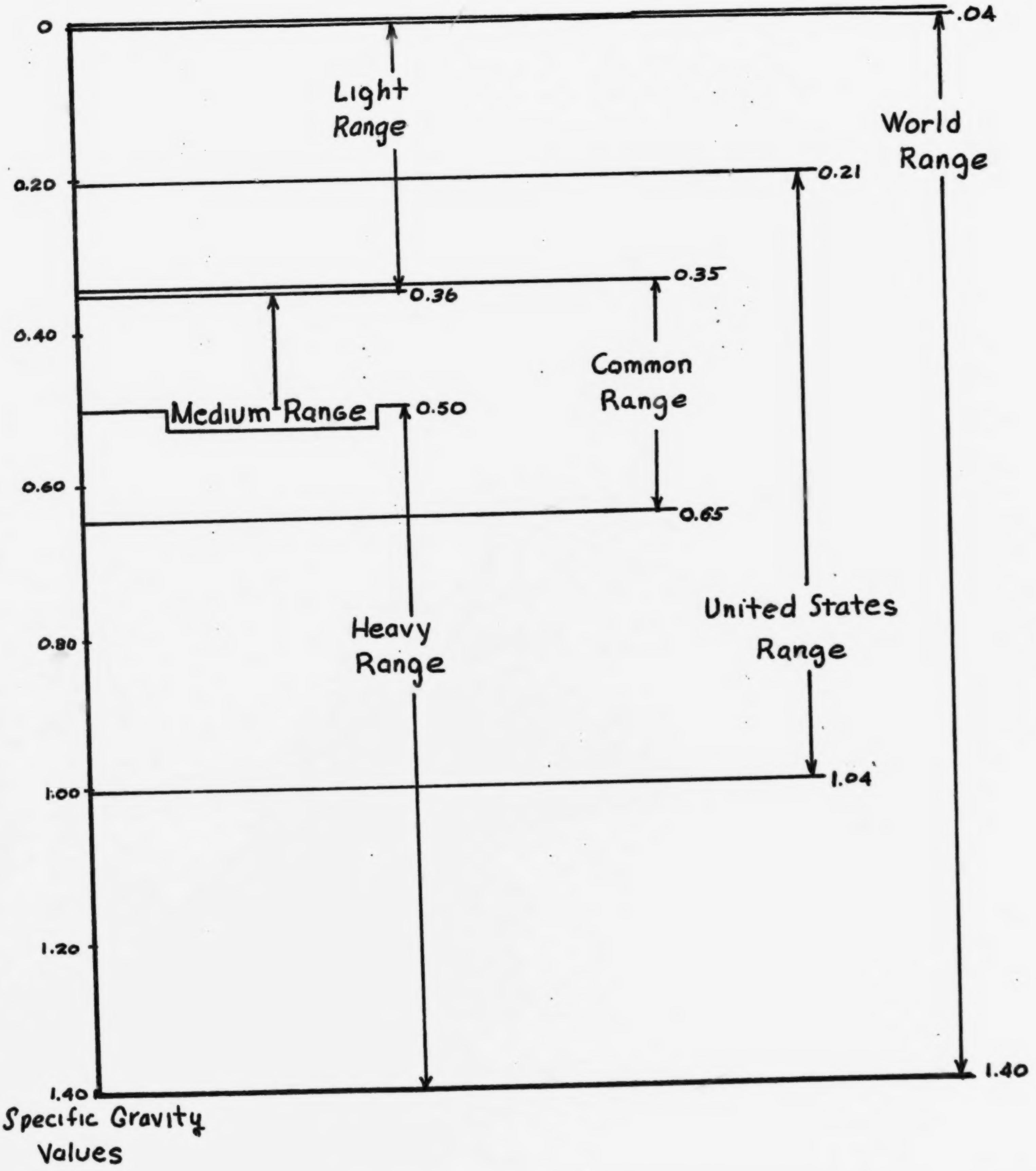
$$S.G. = \frac{\text{Float level Value}}{\text{Total length}}$$

$$S.G. = \frac{5.9''}{10''}$$

$$S.G = 0.59$$

SPECIFIC GRAVITY
WOOD

United States and World Ranges



Experiment
Specific Gravity

The Rapid-Flotation Method for Determining The Approximate Specific Gravity of Wood

I. Materials

A. Assorted pieces of lumber; soft and hardwoods, 1" x 1" x 10". Suggested species might be: oak, hickory, ash, cottonwood, willow, pine, fir, cedar and redwood.

B. A transparent cylinder, filled with water, in which the samples can be made to float on end.

II. Introduction

Specific gravity is a very useful value in helping understand wood as a useful material for man. It has a correlation with strength which is an important feature.

It is an indication of cell size, cell wall thickness and how these two properties are interrelated. If fibers are thickwalled and show small cell cavities, air space is relatively small and S. G. tends to be high. If the fibers are thin walled or have large cavities or both, S. G. will be low.

Specific gravity is a ratio of wood weight, oven dry, to an equal volume of water. Due to shrinkage of the wood the weight of the volume of water displaced must be given at a given moisture content below the fiber saturation point.

Specific gravity of wood based on green volume is one of the most useful and commonly cited values. Standard S. G. setups are time consuming and laborious. This short-cut method will prove satisfactory 90 or more percent of the time.

$$\text{Specific Gravity} = \frac{\text{oven dry weight of wood}}{\text{weight of the displaced volume of water}}$$

III. Procedure

1. Take the wood blocks and size to 1" x 1" x 10".
2. Mark the block into one inch increments.
3. Insert the block into a cylindrical tube lengthwise so the block floats in an upright position.
4. Read the water level on the block as accurately as possible. If the block is remarked into ten parts only in the inch increment of the water line an accurate reading can be had.

5. Observe the pictorial representation on illustrated sheet.

IV. Suggestions

1. In the Textbook of Wood Technology, by H. P. Brown, A. J. Panshin and C. C. Forsaith, MrGraw Hill Book Company, Inc., 1952, pp. 466-467, values can be calculated on a volume basis for a test block with any known moisture content. This is possible only below the fiber saturation point.

2. When materials have two or more laminations of different wood species like in some plywoods, the flotation method nicely calculates the specific gravity.

V. Discussion

1. How does your data compare to those published by the Forest Products Laboratory as recorded in their publication Number 72, Wood Handbook?

2. Why is specific gravity an important physical property of wood?

California State College
Long Beach
Wood Technology
Porosity of Wood

Purpose: To emphasize one of the major characteristics employed in the classification and identification of woods.

Apparatus required:

- Porosity gauge
- Sample wood discs:
    - Walnut
    - Red Oak
    - Redwood
    - Birch
    - Pine
    - White Oak
    - Mahogany
    - Ash
- Compressed air and regulator

Experiment:

1. Attach the porosity gauge to the air source.

2. Remove the gauge cap of the porosity gauge and drop in the pine disc. Replace the cap and tighten firmly. Turn on the air and adjust the regulator for 30 lbs. pressure. Once this calibration has been set, the rest of the experiment may be conducted without further adjustment.

3. Each one of the eight discs will be placed in the porosity gauge and subjected to 30 lbs. pressure for a period of one minute (60 seconds). At the end of that time a reading will be made on the porosity gauge and the results recorded.

4. A comparative bar graph on the porosity of various woods is to be constructed. Group the hardwoods and softwoods separately.

Questions:

1. Why is the understanding of "wood porosity" important for the student of wood technology?

2. What is meant by the term "porous" as it is used in wood evaluation?

3. What woods are classified as "porous"?

4. What structures are responsible for the "blocking" or plugging of the pores?

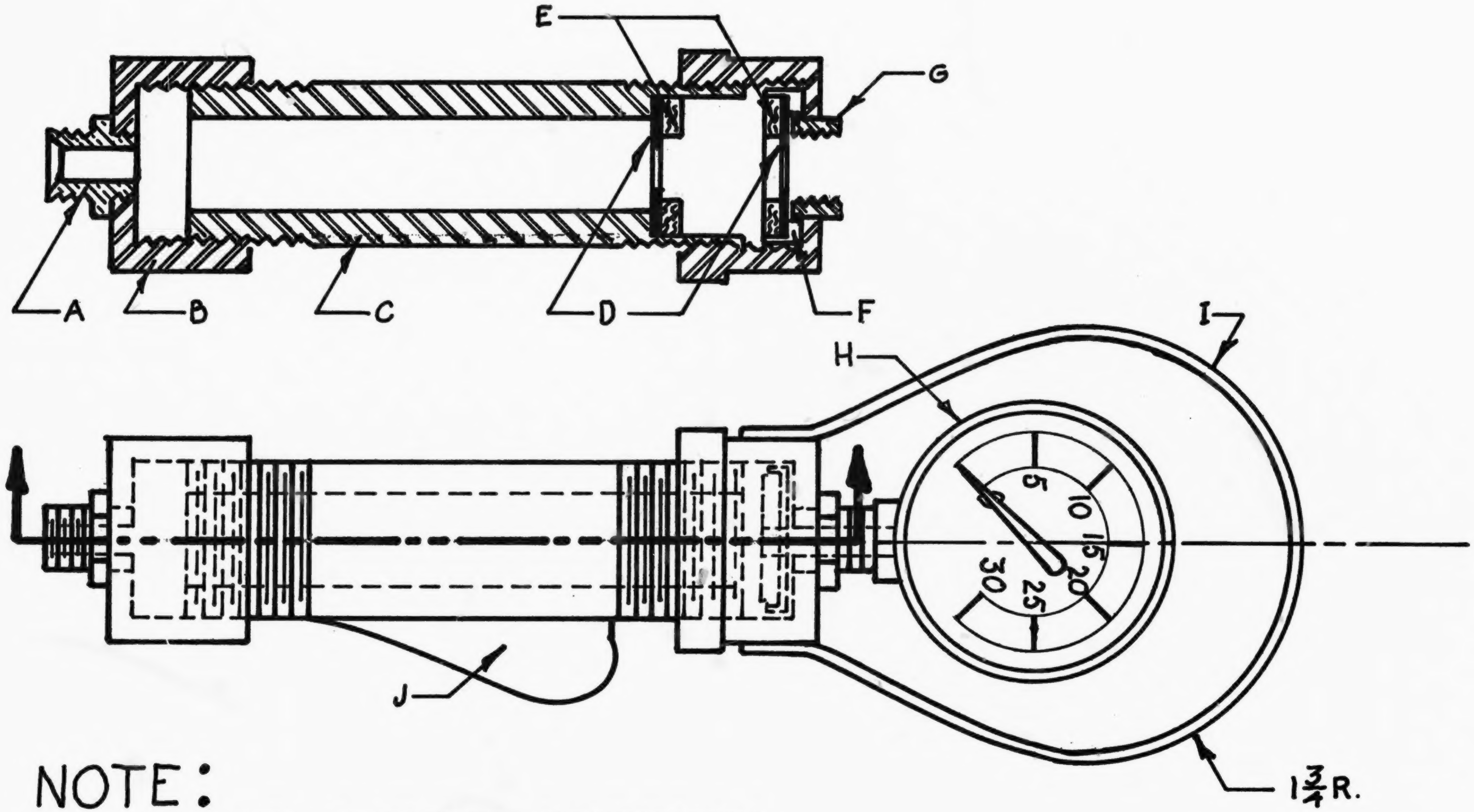
5. In the construction of projects, where will the knowledge of porosity be helpful?

6. What conclusions can be drawn from this experiement?

Reference:

Panshin, Zeeun, Brown, Textbook of Wood Technology, Vol. I

U.S. Dept. of Agriculture, Wood Handbook



E
G
A
B
C
D
F
I
H
0
5
10
15
20
25
30
J
1¾ R.

NOTE:

SEE ATTACHED SPECIFICATION
SHEET FOR PARTS INFORMATION

POROSITY-PERMEABILITY GAUGE

CALIFORNIA STATE
COLLEGE
LONG BEACH

SPECIFICATIONS
FOR
POROSITY - PERMEABILITY GAUGE

* * * * * * * *

CALIFORNIA STATE COLLEGE
LONG BEACH

* * * * * * * *

WOOD TECHNOLOGY

PART.	QUANTITY	DESCRIPTION	OTHER SPECIFICATIONS
A.	1	CONNECTOR, air hose, brass, 1/4" standard fitting.	None
B.	2	CAP, 3/4" pipe, Machined O.D. 1-5/8", length 1-1/8".	One cap is to be drilled and tapped for 1/4" air hose connector Second cap to have raised and knurled shoulder, O.D. 1-3/4".
C.	1	NIPPLE, standard 3/4" pipe. 4-1/2" length.	Bored one end 1-3/32" dia., 7/8" deep producing a square shoulder.
D.	2	WASHER, thin gauge steel, 1-3/32 O.D., 1/4 I.D.	None
E.	2	WASHER, rubber, standard garden hose variety.	None
F.	1	RETAINER, swiveling, for hose washer.	Rimmed to grip hose washer.
G.	1	RETAINER, washer swivel.	Brazed to second cap, drilled and tapped for connecting pipe of pressure gauge.
H.	1	GAUGE, air pressure, 0-30 lb. reading.	U.S. Gauge Co. #15541-1 or equivalent.
I.	1	GRIP RING, for cap.	1/8" x 3/8" strap steel welded to gauge cap.
J.	1	GRIP, for thumb on tester barrel.	Welded to barrel between threaded ends. Projection is 1", and nearest the bored end.

THERMAL CONDUCTIVITY, HEAT AND ENERGY PROPERTIES OF WOOD

" In many situations the ability of wood to resist the passage of heat, electricity, or sound, is of greatest importance." (Desch, P.145)

I. Thermal Conductivity - Depends on Two factors:
- A. Specific Conductivity - rate at which heat travels throughout a material.
  - 1. Anisotropic in wood
    - a) Heat travels 2-3 times faster along the grain than across it.
  - 2. Dense Woods conduct heat more readily than light, porous woods.
  - 3. Calculation of thermal conductivity by formula:

$$K = \frac{Qx}{(T_1 - T_2)\ A\theta}$$

Q = Heat expressed in B.T.U.
x = Thickness of test panels in inches
T_1= Temperature on the hot side of panel in Fahr.
T_2= Temperature on the cold side of panel in Fahr.
A = The area (expressed in Sq. Ft.) through which the measured quantity of heat passes.
o = Time in hours

- B. Specific Heat - The amount of heat (in calories) required to raise the temperature of one gram of material 1° centigrade.
  - 1. The specific heat of wood is 50% higher than that of air, 400% higher than that of copper.
  - 2. Specific heat is a disadvantage in kiln drying, but moisture in green wood eases the disadvantage by its ability to conduct heat.
  - 3. Timber in use shrinks with heat due to moisture loss, though dry wood expands with heat,. Moisture loss overpowers heat expansion
  - 4. High specific heat and poor conductivity effective in reducing fire spread for a considerable period of time.
    - a) Wood is fire retardant though highly combustible.
      - (1) Due to formation of char which insulates against the heat of flame.
      - (2) Final failure due to shrinkage and resultant check thus exposing uncharred fuel to flame.
    - b) Fire resistance comparison experiment (see accompanying pages).

THE ELECTRICAL PROPERTIES OF WOOD

Due to the technical nature of the subject matter, the author of this section chooses not to reduce the content of this section to any more brief form than accompanying paper presented to him by one of his students at California State College, Long Beach, California.

by

Harrison L. Ley

CALIFORNIA STATE COLLEGE

LONG BEACH

WOOD TECHNOLOGY

Fall of 1965

Instructor - Mr. Quinones

Wood has a surprisingly large number of electrical properties for a material which is not normally thought of in terms of electrical circuits and equipment. Some of these properties are easily measured while others require special equipment, or must be arrived at by intricate calculations. This paper will be an attempt to identify, define, and explain those electrical properties of wood which will be of significance to someone studying Wood Technology for the purpose of teaching Industrial Arts woodworking.

I. INSULATION RESISTANCE

A dielectric is a material which will not readily conduct electrical currents. Such materials as glass, mica, rubber, and wood are classified as dielectrics. The degree to which any dielectric will resist the flow of electrical currents is termed its insulation resistance. Insulation resistance is measured by a device called a megohm meter. The megohm meter or megger is essentially a resistance bridge and galvanometer circuit which normally is used to apply 50 or 500 volts DC to the material being tested. By rotating the adjusting knobs on the megger until a null is reached on the galvanometer, the insulation resistance (measured in megohms) can be read directly.

It has been found that the insulation resistance of wood varies with its moisture content and its density. However, variations in moisture content have a far greater effect on insulation resistance than do changes in density. For this reason the measurement of insulation resistance has become a widely accepted means of determining the moisture content in lumber. In practice a small hand held megohm meter is used which is connected to two steel probes. The probes are imbedded into the wood to be tested at a distance of 1-1/4" and to a depth of 5/16". The meter which is calibrated in per cent moisture can then be used to directly read the moisture content of the wood under test. This method is far faster and less wasteful than the previous method which required the removal of a board from the stack, the cutting of a specimen from the center of the board, the weighing, drying, then the reweighing of the specimen followed by the calculations necessary to determine its moisture content.

Insulation resistance which is quite often referred to as direct current resistance or DCR has been found to vary from species to species at any given per cent of moisture content. This condition is attributed to the presence, in varying degrees, of minerals, water soluble salts, and other dissolved electrolytic materials in the cells and fibers of the wood.

It has also been found that DCR increases in a nonlinear fashion with linear increases in moisture content.

There is another area, in addition to the determination of moisture content, where the insulation resistance of wood is quite important. Wood having a high DCR must be selected for cross arms and poles to support secondary power transmission lines, since these provide a potential leakage path to ground through which power is lost. It is for this reason that preservatives used for poles and cross arms are of the non-electrolytic type. Creosote and other petroleum based products have proven highly satisfactory for this application, but mineral salts must be avoided.

Traditionally lineman's tools have had insulating handles made from birch because of its high insulation resistance, but recently there has been a move to replace wood handles by fiberglass since the fiberglass provides greater strength and even higher DCR values.

Occasionally the term specific resistance may be encountered. Specific resistance is defined as the resistance per unit volume of material. With respect to wood it is the resistance in megohms per cubic centimeter at a prescribed moisture content and temperature. The inclusion of temperature in this definition is significant because the DC resistance doubles for each decrease in temperature of 22.5 degrees F.

II. DIELECTRIC STRENGTH

Dielectric strength is defined as that ability of a dielectric material to withstand an applied voltage for a prescribed period of time without puncturing. Years ago the measurement of dielectric strength of wood was considerably more important than it is today. With the development of new synthetic materials for insulation, together with demands for higher voltages and higher frequencies, the use of wood in its natural form as an insulator is seldom seen. However, new wood derivatives such as Compreg, which has proven to be highly effective as an insulating material, may reverse the trend.

III. DIELECTRIC CONSTANT

As was pointed out earlier, wood is considered to be a non-conductor or dielectric material. As with all dielectric materials wood will pass some current if the applied voltages are sufficiently high. When an electrode is placed on each side of a dielectric material and an alternating current is applied to the electrodes, a capacitive charging and discharging takes place within the dielectric. Dielectric constant for wood is defined as the ratio between the capacitance of a capacitor using wood as a dielectric compared with a capacitor of like configuration using dry air or vacuum as the dielectric. Since the dielectric constant of a capacitor employing dry air or vacuum is unity and the dielectric constant of water is approximately 81 we can expect wood to fall somewhere between. As an example the dielectric constant for oven dried oak as given in Table I, is 3.1. As the moisture content increases the dielectric constant will also increase.

TABLE I

Values of Dielectric Constant and Power Factor for Various Woods at Radio Frequencies (Between 80 and 1875 KC)

Species	Dielectric Constant	Power Factor in Per cent
Basswood	2.0	1.92
Baywood	2.4	2.45
Cypress	2.0	2.1
Fir	3.1	3.5
Maple	2.6	2.45
Oak	3.1	2.97
Birch	5.2	6.48

IV. POWER FACTOR

In any direct current circuit the current flowing is directly proportional to the applied voltage and inversely proportional to the resistance of the material. Thus, if a piece of wood was sandwiched between two plates and a DC voltage applied to it the amount of current which would flow would depend on the value of the voltage applied and the value of the inherent resistance of the material. If an alternating current were applied to those same plates the amount of impedance to current flow would be dependent upon the frequency of the applied voltage. With any capacitive AC circuit there is developed a capacitive reactance and a condition where the current leads the applied voltage by a certain angle (Phi.) The cosign of angle Φ is the ratio of the actual current flowing through the circuit, as to compared to the current which would flow through a similar circuit if it were purely resistive. Stated in another way power factor is the ratio of power absorbed to the apparent power stored.

The understanding of Power Factor and Dielectric Constant is important to the Industrial Arts teacher for the following reason: like any dielectric, wood can be heated by exposing it to high frequency (AC) electric currents either by placing the wood between electrodes (plates) or by placing it in the flux path of an induction coil through which high frequency current is passing. The amount of heat generated in the wood depends upon the power factor and on the dielectric constant. This principal is widely employed in the woodworking industry through the use of Wood Welders and similar devices. Wood welding is simply a technique for internally heating a glue line in a wood joint by exposing it to high frequency currents.

The electric energy which is absorbed by the wood is converted to heat energy which serves to rapidly set the glue joint.

Although it is possible to delve more deeply into the characteristics and behavior of wood when exposed to certain electrical stresses, the foregoing information should be sufficient for dissemination to the average Industrial Arts class.

BIBLIOGRAPHY

1. Langford - Smith, F., Radiotron Designer's Handbook, Fourth Edition (Harrison, New Jersey - Radio Corporation of America, 1953).

2. Henney, Keith, The Radio Engineering Handbook, Third Edition (New York, McGraw-Hill Book Company, Inc., 1941).

3. Terman, F. E., Radio Engineers' Handbook, First Edition - Eighth Impression (New York - McGraw - Hill Book Company, Inc., 1943).

4. U. S. Department of Agriculture, Wood Handbook, Agriculture Handbook No. 72, (U. S. Government Printing Office, 1955).

THE ACOUSTICAL PROPERTIES OF WOOD

I. The acoustical properties of wood are important to the musical instrument industries and in building construction.
  A. Law of Acoustics - The power of conducting or cutting sound is linked with elasticity.
    1. Wood fixed to allow free vibration will emit sound.
      a) Dependent on the natural frequency of vibration of the piece, and length of piece from fixed end(s)
      b) Also dependent on density.
        (1) High density - greater conductivity and vibration.
        (2) Deacyed wood or low density wood, no ring when struck.
      c) Wood is resonant
  B. Uniformity of texture necessary for resonance
    1. Must be free from defects.
    2. Must be properly fixed for optimum performance.
  C. In order for wood to absorb sound:
    1. Must have large mass.
    2. Must be fixed to reduce or completely stop vibration.
    3. Must be low in specific gravity.
    4. The cellular structure of wood causes wood to absorb sound if rigidly fixed. (hollow, air filled spaces)

MOISTURE CONTENT OF WOOD

I. Moisture content is that weight of water contained in wood and expressed as a percentage of the ovendry weight of the wood.

  A. The distribution of moisture is located in the cells and the cell walls of wood.
    1. Free water is the water found in the lumina of the cells.
    2. Bound water or hygroscopic water is the water that is found in the cell walls.

  B. The fiber saturation point of wood is that point at which the cell wall is saturated, but no free water remains in the cell (appx. 30 percent).
    1. The fiber saturation point is important for three reasons:
      a) More heat is required to move water from the wall than from the cavitity.
      b) A wood cell will not shrink until it reaches the fiber saturation point.
      c) Large changes in the physical and mechanical properties of wood begin to take place at the fiber saturation point.

  C. The equalibrium moisture content of wood is when wood has reached a stage when there is no further interchange of moisture between the wood and that of the atmosphere.
    1. This steady moisture content depends on the relative humidity and the temperature of the surrounding air; it fluctuates with changes in one or both of these atmospheric conditions.

II. There are several ways to determine the moisture content of wood such as electrical, relative-humidity, chemical and the oven-dry method. In this report only the oven-dry method will be considered.

  A. The oven-dry method consist of selecting representative sample boards of pieces from the material to be tested, cutting moisture sections from each sample, weighing each, drying each in an oven to constant weight, weighing each again, and calculating the moisture content.

  B. The proper selection of sample, the preparation, the weighing, the drying, weighing the oven-dry section and calculating the sample is very important. Fig. 1 shows steps in calculating the moisture content by the oven-dry method.

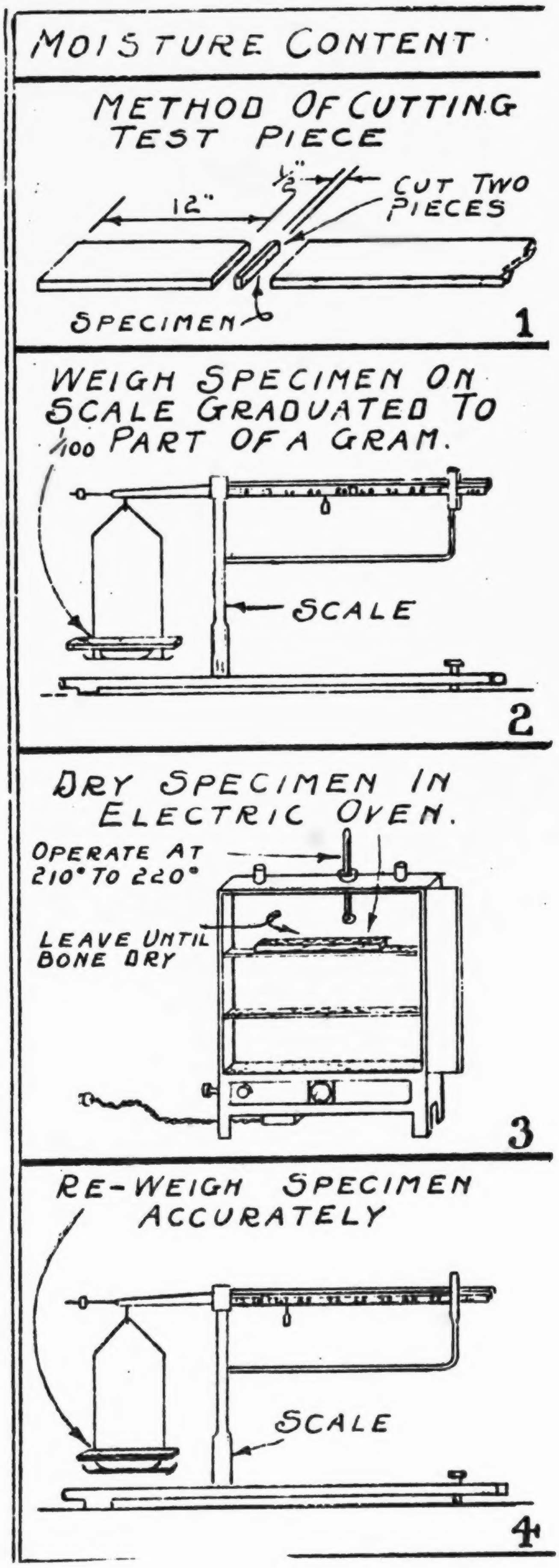

MOISTURE CONTENT
METHOD OF CUTTING TEST PIECE
12"
½"
CUT TWO PIECES
SPECIMEN
1
WEIGH SPECIMEN ON SCALE GRADUATED TO 1/100 PART OF A GRAM.
SCALE
2
DRY SPECIMEN IN ELECTRIC OVEN.
OPERATE AT 210° TO 220°
LEAVE UNTIL BONE DRY
3
RE-WEIGH SPECIMEN ACCURATELY
SCALE
4

FIGURE I

C. The formula for determining the moisture content is: Moisture content equals the green or original weight minus oven-dry weight times one hundred divided by the oven-dry weight.

III. The wood technologist should have an understanding of how wood dries, what causes moisture to move in wood and of the factors that influence the rate of moisture movement.

A. Water in wood normally moves from zones of higher to zones of lower moisture content.

B. Moisture in wood moves through several kinds of passageways, such as resin ducts in softwoods, through cell cavities and small openings in cell walls called pits.

C. When wood is drying, several forces may be acting to reduce its moisture content, and they all may be acting at the same time.
  1. Capillary action is the force that causes free water to flow mostly through cell cavities and small openings in the cell wall.
    a) When wood starts to dry, evaporation of water from the surface cells sets up forces that exert a pull on the free water in the zones of layers of wood beneath the surface and a flow results.
  2. Differences in relative humidity that causes moisture that is in the vapor start to flow through various passageways.
    a) Moisture evaporated from wood moves to the surface by two types of diffusion that act at the same time. At high temperatures diffusion of water vapor through the larger passageways is the most important, while at low temperatures most of the moisture diffuses through the passageways within the cell walls.
  3. Differences in moisture that move the hygroscopic water through passageways in the cell wall.
    a) The differences are very important in low temperature drying.

IV. Dimensional changes take place when the wood is been dried below the fiber saturation point.

A. When wood has dried to 15 percent moisture content, about one half of the total possible shrinkage has taken place.

B. When dried to 8 percent moisture content, nearly three-fourths of the maximum possible amount has taken place.

C. Shrinkage takes place chiefly in the radial and tangential directions, that is, at right angles to and parallel to the annual rings.
  1. The ratio of radial to tangential shrinkage is about 1 to 2.
  2. The shrinkage along the grain (longitudinally) is very little.
  3. Figure 2 shows how boards shrink radially and tangentially.

D. Changes in the moisture content of wood as it dries are responsible for many seasoning defects.
  1. Cupping is the warping of the face of a plank or board so that it assumes a troughlike shape, the edges remaining approximately parallel to each other (Figure 3).
  2. Crooking is the longitudinal warping, edgewise, from a straight line drawn from end to end of the piece (Figure 3).
  3. Bowing is the longitudinal warping, flatwise, from a straight line drawn end to end of the piece (Figure 3).
  4. Twist is the distortion of both sides and edges (Figure 3).
  5. Casehardening is the term applied to dry lumber with nearly uniform moisture content but characterized by the presence of residual stresses, tension in the interior of the piece (core) and compression in the outer layers of cells (shell). (Figure 4 shows steps in testing for casehardening.)
  6. Checks are ruptures along the grain that develop during seasoning either because of a difference in radial and tangential shrinkage or because of uneven shrinkage of the tissue in adjacent portions of the wood. (Figure 5 shows examples)
  7. Honeycombing is the internal splitting in wood that develops in drying; caused by internal stresses or by closing of surface checks.
  8. Collapse is the defect that sometimes develops above the fiber saturation point when very wet heart wood or certain species is dried; evidenced by abnormal and irregular shrinkage.

V. Green lumber can be seasoned to the necessary dryness by combining outdoor air seasoning (air drying) with subsequent further drying in a heated room (kiln drying).

A. Air-drying of wood consist of piling the lumber outdoors so that the air currents can circulate through the pile and carry away the moisture from the surfaces of the wood.
  1. The air-drying of lumber is dependent upon the temperature and relative humidity of the outdoor

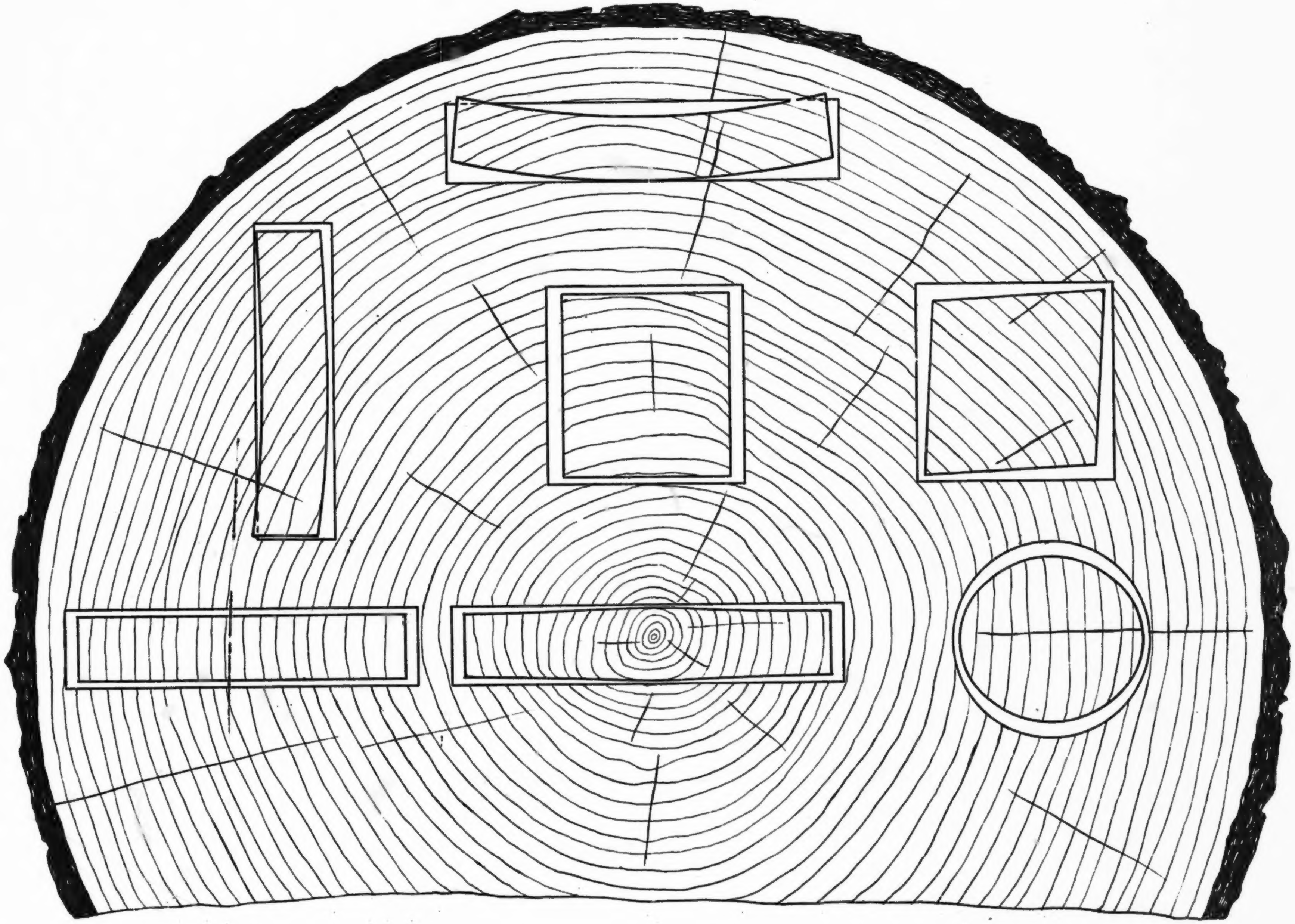
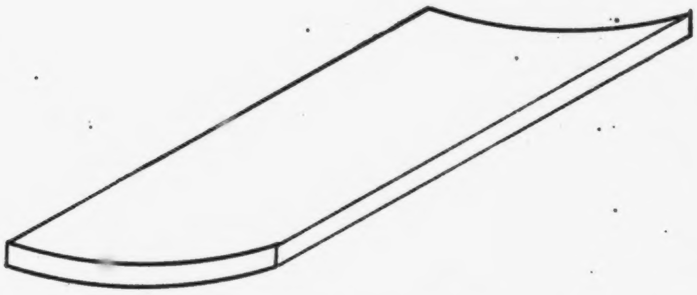
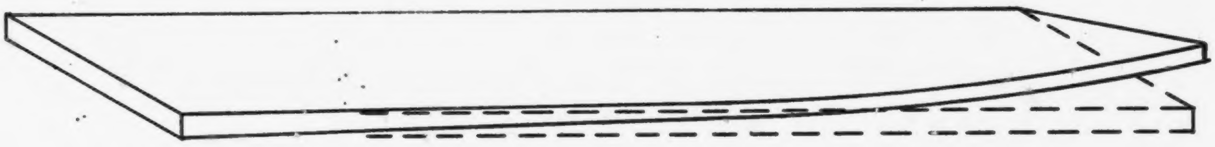


Figure 2.--Characteristic shrinkage and distortion of flats, squares, and rounds as affected by the direction of the annual rings. Tangential shrinkage is about twice as great as radial shrinkage.

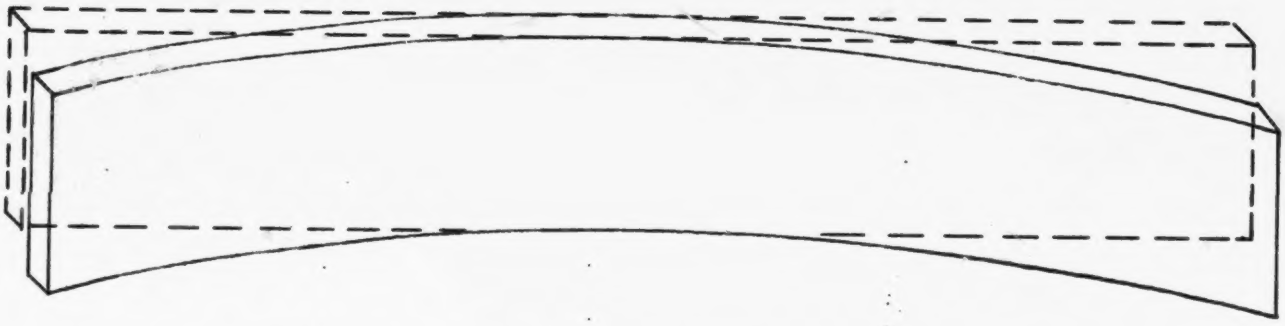
TYPES OF WARP



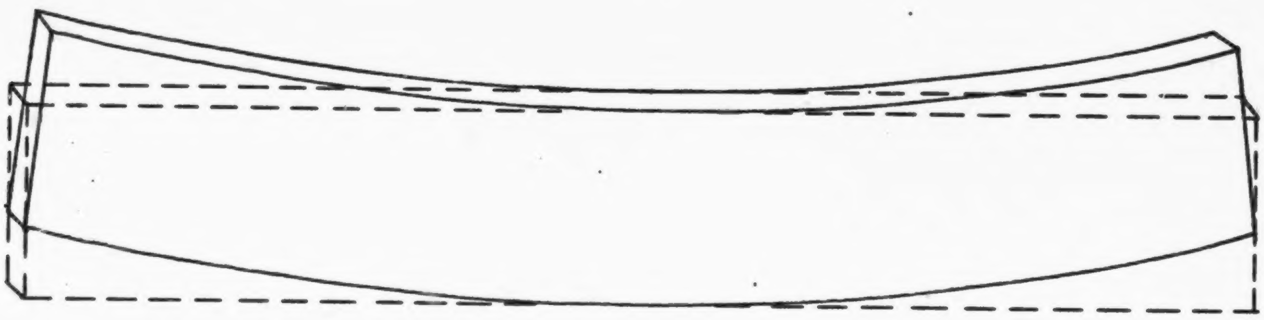
CUP is the distortion out of square with the sides between the edges.



TWIST is the distortion of both sides and edges.



BOW is the distortion out of square with the sides between the ends.



CROOK is the distortion of the edges.

Figure III

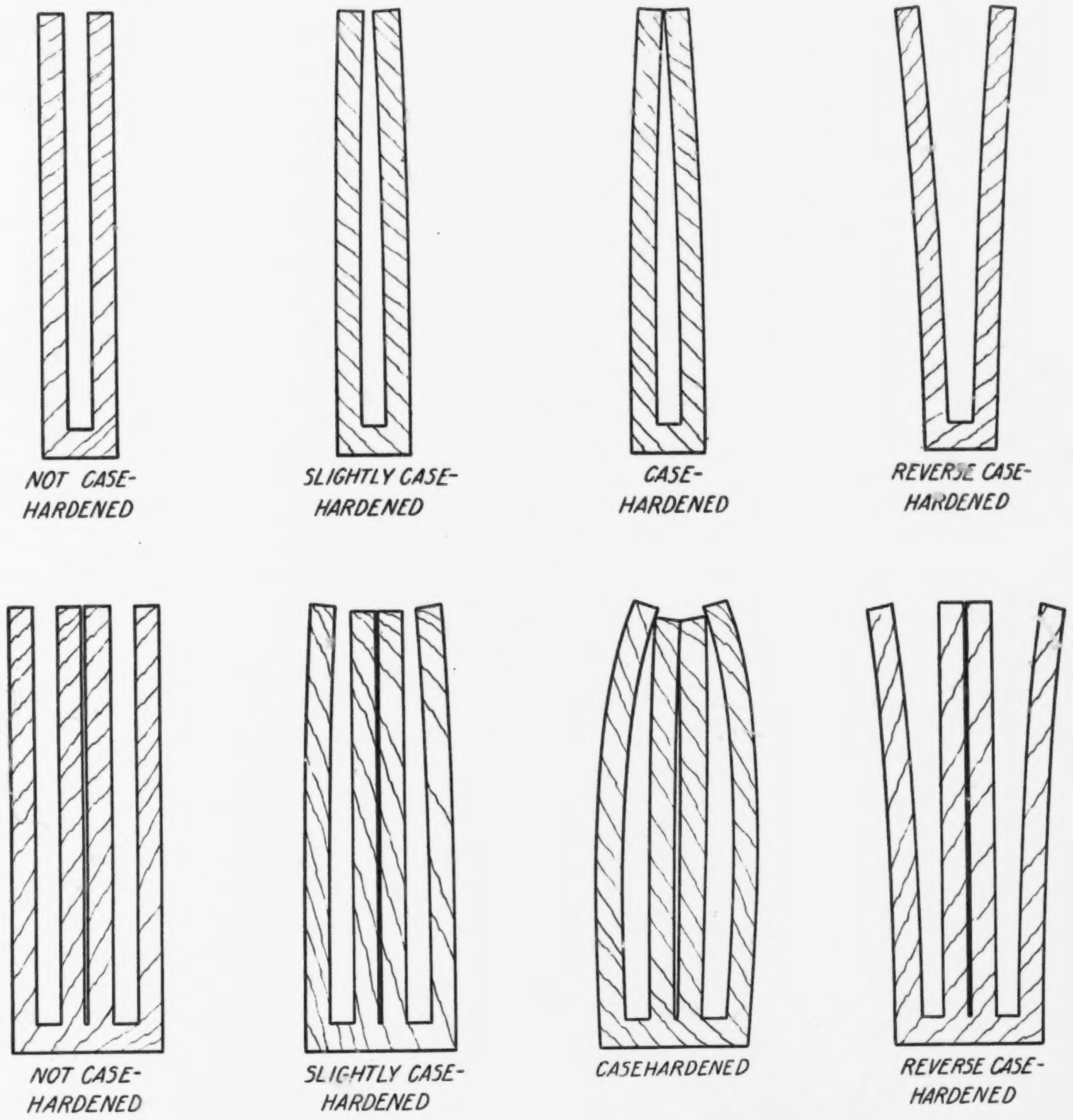
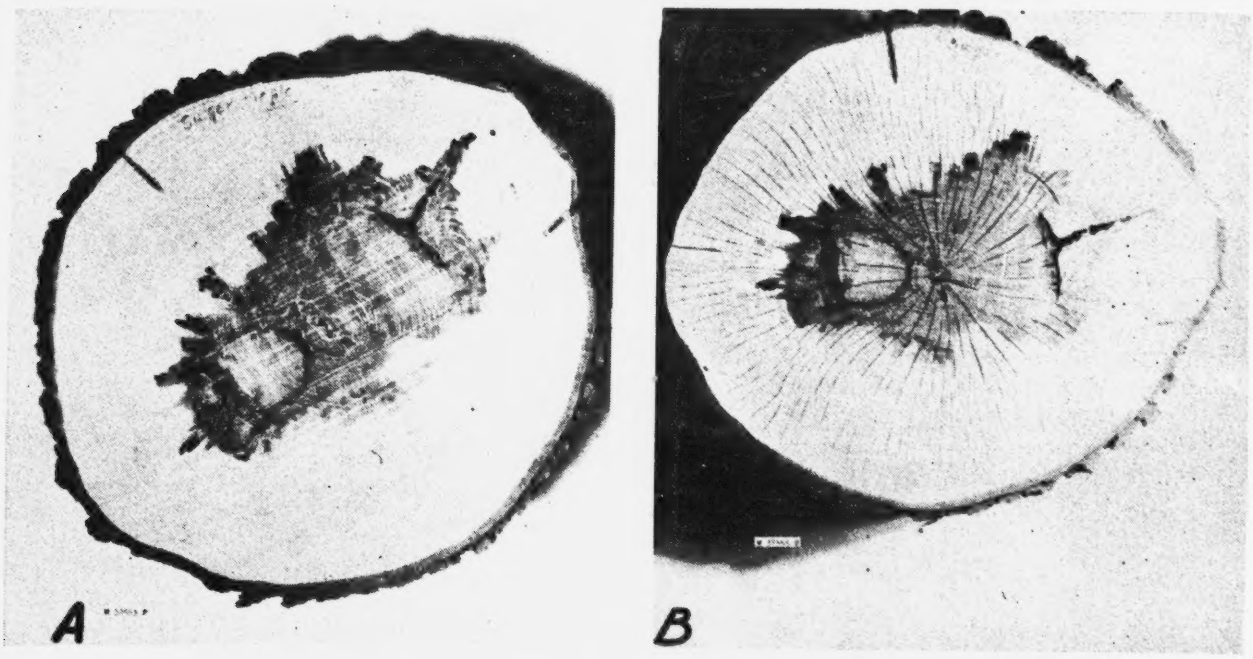
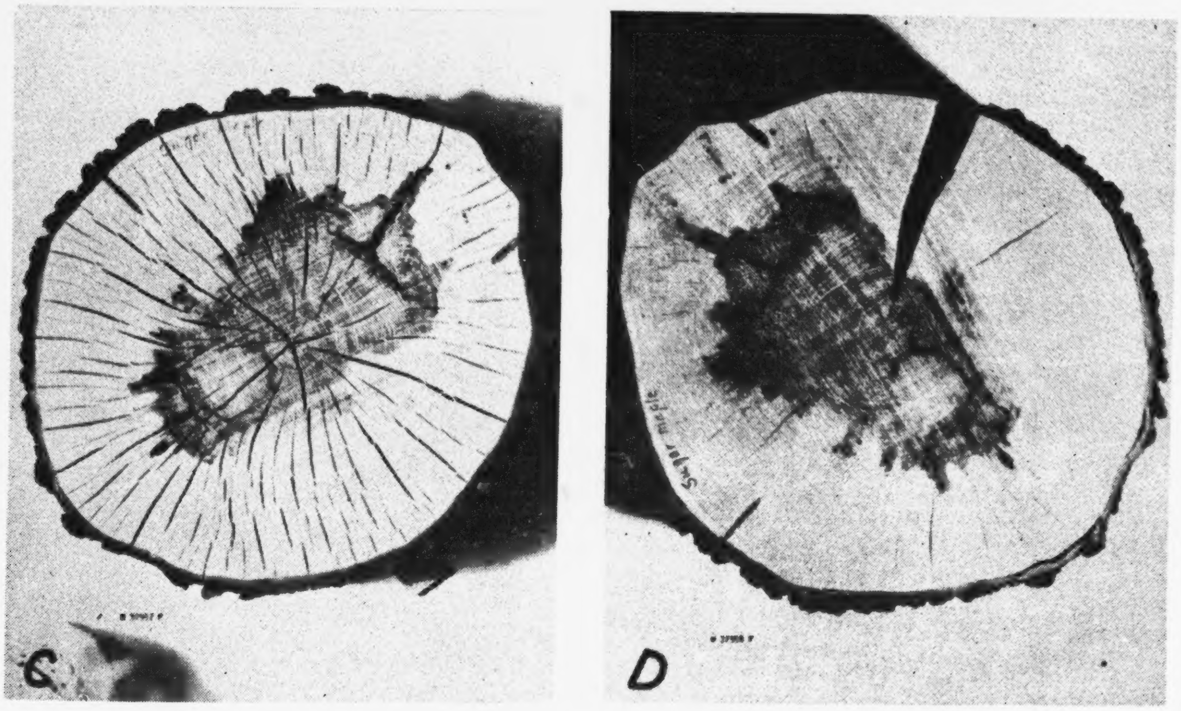

NOT CASE-HARDENED
SLIGHTLY CASE-HARDENED
CASE-HARDENED
REVERSE CASE-HARDENED
NOT CASE-HARDENED
SLIGHTLY CASE-HARDENED
CASEHARDENED
REVERSE CASE-HARDENED

Figure 4.--Method of cutting specimens for case-hardening tests. Material that is less than 1-1/2 inches thick is cut into three prongs and the center prong is removed; material that is 1-1/2 inches thick or thicker is cut into six prongs and the second and fifth prongs are removed.



Beginning of seasoning; no checks.

Early stage of seasoning; numerous small checks.



Later stage of seasoning; size of some checks increased with closing of others.

Final stage of seasoning; almost complete closing of most checks when major stress is relieved by large V-shaped check.

Figure 5

air, precipitation, and the air circulating within the pile.

2. The active drying period is ideally the time of high temperature and low relative humidity.

B. The air-drying of lumber is affected by local factors, such as elevation, drainage, and topography conditions.
   1. The air-drying yard is preferably located on high ground that is level, well drained, and not adjacent to water bodies or wind-obstructing objects such as tall trees and buildings.
   2. The ground surface should be kept free from debris and vegetation.

C. Kiln drying is a process designed to hasten drying by carefully placing lumber in a chamber called a kiln,and circulating large volumns of heated air through it.
   1. A dry kiln consist of one or more chambers, rooms, or tunnels in which air can be circulated around the wood being dried.
   2. The temperature and the relative humidity can be manually or automatically maintained by controlling the dry- and wet-bulb temperatures.
   3. A properly designed and operated kiln will dry most species of lumber to any specified moisture content between 3 and 15 percent in a reasonable short time.
   4. Once lumber has been dried, it is desirable that it be kept dry until fabrication is completed.

D. There are a number of distinct and important advantages in seasoning.
   1. Seasoning reduces the likelihood of stain, mildew, or decay developing in transit, storage or subsequent use.
   2. The shrinkage that accompanies seasoning can take place before the wood is put to use.
   3. Wood increases in most strength properties as it dries below the fiber saturation point.
   4. The strength of common fasteners such as nails and screws is greater in seasoned wood than in green wood after assembly.
   5. Glued wood products can be expected to perform better when the moisture content of the wood at the time of gluing is as near as practicable to the average moisture content which the product is expected to have in service, provided it is below some 15 to 18 percent.
   6. Seasoning reduces the possible damage from insects that bore holes in wood in either the larval or adult stage.

7. The electrical resistance of wood changes greatly as it dries.
8. The appreciable reduction in weight accomplished by seasoning is an important factor in reducing shipping cost.

California State College
Long Beach
Wood Technology
Experiment
Moisture Content of Wood

Purpose: To enable the student to determine the suitability of a wood for construction pruposes, through an evaluation of moisture content.

Apparatus Required:

Oven - with thermostatic control
Balance
Wood samples
Graph materials

Experiment:

1. Three, one inch cross-sections of wood must be obtained from approximately twelve inches from the end of the stock to be tested. The width and thickness of the stock has no bearing on the test, but the samples should be solid and free from defects.

2. Label the sample pieces, then weigh and record the weight of each piece.

3. Place the samples in an oven heated to a temperature of between 214 and 221 degrees Fahr. Weigh the pieces every thirty minutes and record their weight. Continue this process until a constant weight is reached (up to 24 hours). If this process cannot be continuous, then the samples can be removed from the oven, allowed to cool slightly, then sealed in an airtight plastic bag. Before starting the process again, it is necessary to preheat the oven and maintain a careful control on time.

4. When the wood no longer looses weight, it is considered oven dry. In order to calculate the original moisture content of the samples, the following formula is employed.

$$\frac{\text{Weight of water in the wood}}{\text{Oven dry weight of the wood}} \times 100 - \%\text{ moisture content}$$

5. Find the moisture gradient for each of the samples at the 30 minute intervals and develop a comparative line graph.

Questions:

1. Why are the cross-sections of wood cut from the middle of the piece to be treated?
2. Why does a woodworker need to know the moisture content of the material with which he is building?
3. What are some of the methods used to determine moisture content?
4. What percentage of moisture is recommended for furniture lumber in the Long Beach area?
5. What is the recommended moisture difference between pieces that are to be glued together?

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The Preservation of Wood

I. The Field of Wood Preservation

- A. Wood versus other structural materials

- B. Need for economy in wood use

    - 1. Benefits of wood preservation
    - 2. Development of the wood preservative industry

        - a.)Early development in Europe
        - b.)Development of the industry in the United States

            - (1) Water soluble salt treatment
            - (2) Creosote treatment
            - (3) Classes of material treated
            - (4) Volume of material treated
            - (5) Present opportunities

II. Agencies of Wood Deterioration

- A. Wood inhabiting fungi

    - 1. Decay

        - a.)The cause of decay
        - b.)Decay requirements
        - c.)Spread of decay
        - d.)Effect of decay on wood properties
        - e.)Durability

    - 2. Wood staining fungi
    - 3. Chemical stains
    - 4. Molds

- B. Wood-boring insects on the land

    - 1. Termites

        - a.)Subterranean termites
        - b.)Drywood termites
        - c.)Damp wood termites
        - d.)Natural resistance of wood

    - 2. Powder-post beetle
    - 3. Carpenter ants

C. Marine borers

   1. Molluscean borers

      a.)Shipworm, teredo and bankia
      b.)Martesia

   2. Crustacean borers

      a.)Limnoria
      b.)Sphaeroma
      c.)Chelura

   3. Resistance of woods

D. Fires

E. Mechanical wear

F. Weathering

III. Wood Preservatives

A. Requirement of a good wood preservative

   1. Toxic to wood destroyers
   2. Permanent
   3. Highly penetrative
   4. Safe to handle and use
   5. Harmless to wood and metal
   6. Plentiful
   7. Economical

B. Methods of determining effectiveness

   1. Toxicity
   2. Penetration ability
   3. Chemical properties
   4. Corrosiveness
   5. Fire resistance
   6. Effect on paint
   7. Toxicity data
   8. Service tests
   9. Tests on other properties

C. The principal wood preservatives

   1. Preservative oils, or mixtures of oils, that are of low volatility and only slightly soluble in water

    a.)Coal-tar creosote
    b.)Anthracene oils or carbolineums
    c.)Water-gas tar creosote
    d.)Wood-tar creosote
    e.)Coal-tar
    f.) Water-gas tar
    g.)Solutions of creosote in petroleum or tar

  2. Inorganic salts and similar materials that are used in water solutions

    a.)Zinc chloride
    b.)Chromated zinc chloride
    c.)Sodium fluoride
    d.)Mercuric chloride
    e.)Copper sulphate

  3. Toxic chemicals that are dissolved in some colorless and usually volatile solvent other than water

    a.)Anaconda Wood Preservative
    b.)Basilit
    c.)Bruce Preservative
    d.)Carbolineums
    e.)Chemonite
    f.) No-D-K
    g.)Par-Tox
    h.)Permatol
    i.) Termiteol
    j.) Toxicol
    k.)Wolman Salts
    l.) Zinc-mets-arsenite (ZMA)

  4. Non-preservatives

    a.)Paint
    b.)Stains

IV. Preparation for Treatment

A. Peeling
B. Air seasoning
C. Steaming and vacuum
D. Boiling under vacuum
E. Mechanical preparation

  1. Adzing
  2. Boring
  3. Framing
  4. Incising

V. Wood Preserving Processes

A. Non-pressure process

1. Brush spraying treatment
2. Dipping
3. Steeping
4. Kyanizing
5. Hot and cold bath
6. Charring, charring and spraying
7. Diffusion process
8. Treating standing trees

B. Pressure processes

1. Full-cell process

a.)Bethell process
b.) Burnett process
c.)Miscellaneous

(1) Cellcure treatment
(2) Chemonite treatment
(3) Wolman treatment
(4) Zinc-mets Arsenite (ZMA) treatment
(5) Full-cell treatments not now in use

(a) Allardyce treatment
(b) Card treatment
(c) Creoaire treatment
(d) Ruetgers treatment
(e) Wellhouse method

2. Empty-cell method

a.)Rueping process
b.)Lowry process
c.)Miscellaneous methods using pressure

(1) Boucherie process
(2) Pfister method
(3) Pressure treatment in boring holes
(4) Pressure treatment of pileheads
(5) Cellon process

VI. Factors Affecting Penetration and Absorption

A. Anatomy of wood

    1. Wood tracheids
    2. Resin ducts
    3. Vessels
    4. Wood fibers
    5. Rays
    6. Wood parenchyma
    7. Sapwood and heartwood

  B. Density
  C. Direction of penetration
  D. Preparation of timber
  E. Form and size of timber
  F. Grouping of material for treatment
  G. Treating procedures

    1. Type of process
    2. Character of preservative
    3. Viscosity and temperature
    4. Pressure
    5. Initial, gross and net absorption

VII. Economic Aspects of Preservative Treatments

  A. First cost, in place
  B. Serviceable life
  C. Cost of maintenance
  D. Obsolescence
  E. Salvage value
  F. Influence of preservatives on wood markets

VIII. Properties of Treated Wood

  A. Strength

    1. Effect of treatment
    2. Effect of incising

  B. Inflamability
  C. Painting characteristics

    1. Creosoted wood
    2. Zinc chloride treated wood
    3. Bleeding of creosoted wood
    4. Discoloring effects

  D. Corrosive effects
  E. Electrical resistance

IX. Treating Plants and Equipment

A. Brush and spray equipment
B. Steeping and dipping apparatus
C. Hot-and-cold-bath plants
D. Pressure plants

1. Treating cylinders
2. Heating units
3. Tanks
4. Cranes and hoists
5. Live rolls and conveyor belts
6. Boiler plant
7. Framing machinery
8. Adzing, boring, incising and shaving machinery

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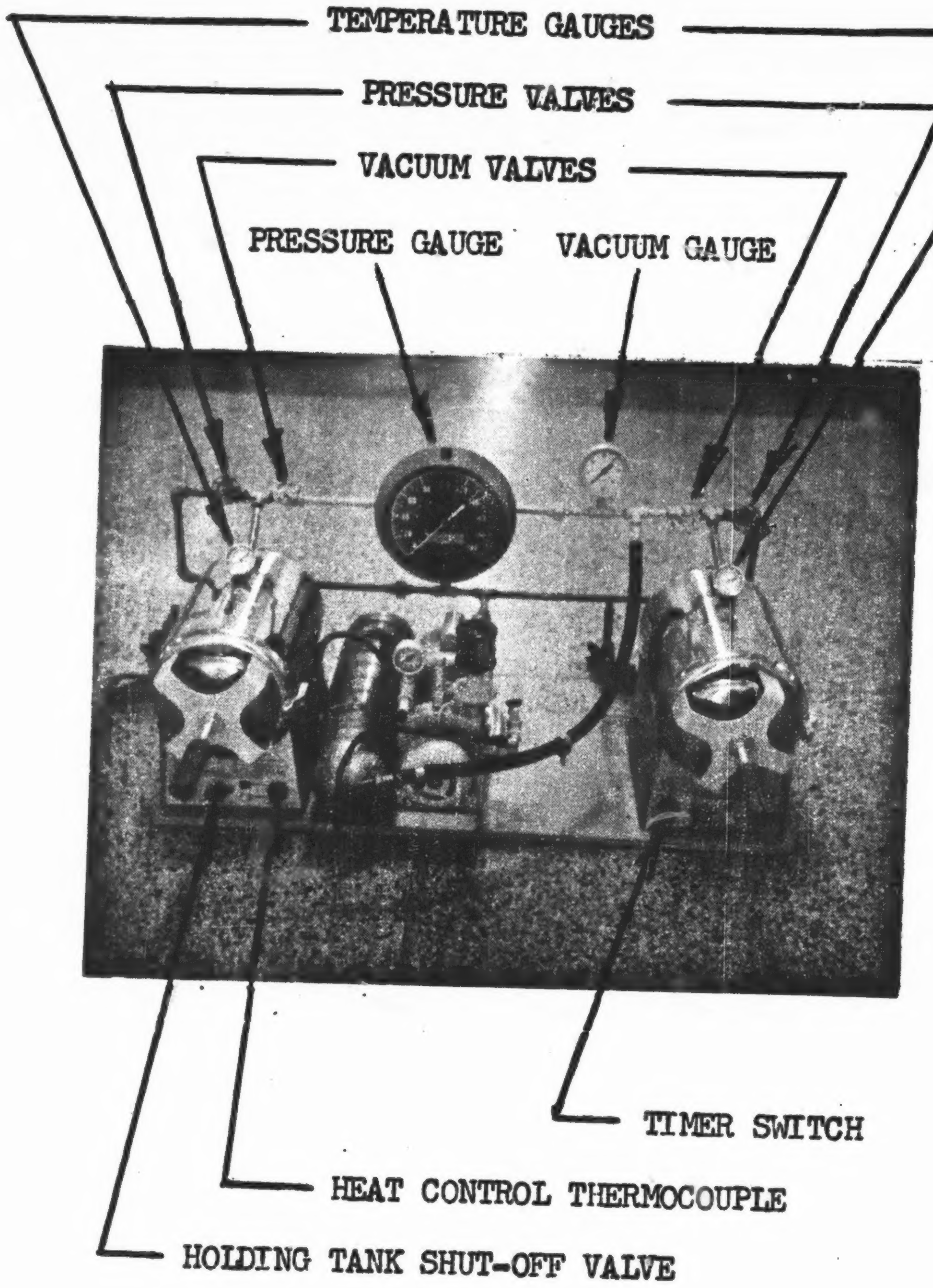
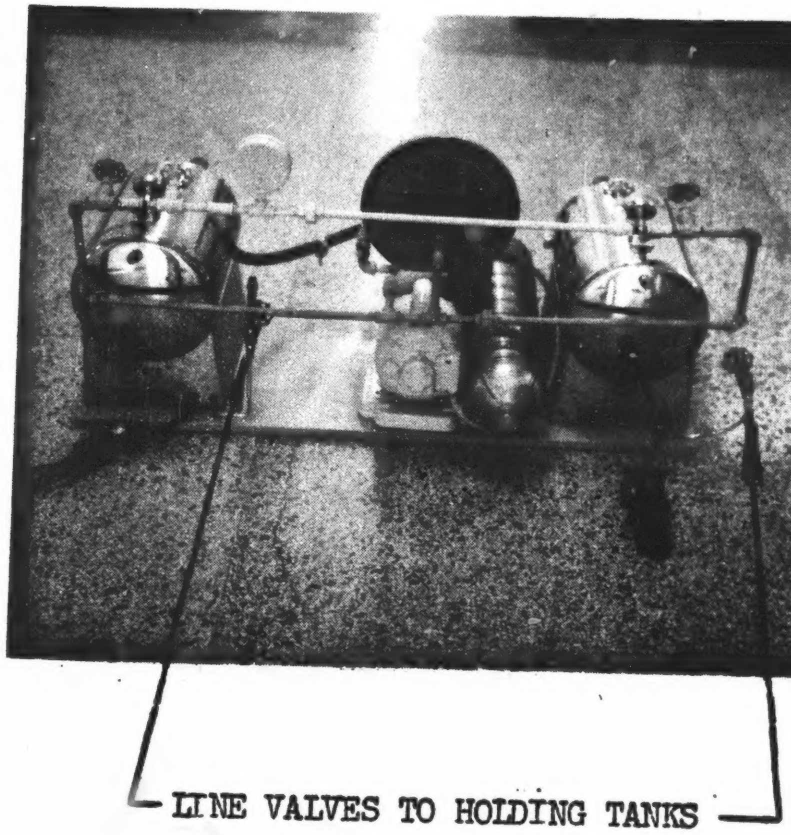

TEMPERATURE GAUGES
PRESSURE VALVES
VACUUM VALVES
PRESSURE GAUGE
VACUUM GAUGE
TIMER SWITCH
HEAT CONTROL THERMOCOUPLE
HOLDING TANK SHUT-OFF VALVE


LINE VALVES TO HOLDING TANKS

PRESSURE TREATMENT

AUTOCLAVE

Louis E. Quinones

GLOSSARY

Annual growth ring: The growth layer put on in a single growth year, including springwood and summerwood.

Bark: Outer layer of a tree, comprising the inner bark, or thin, inner living part (phloem), and the outer bark, or corky layer, composed of dry, dead tissue.

Basic stress: (See Stress)

Bastard sawn: Hardwood lumber in which the annual rings make angles of 30° to 60° with the surface of the piece.

Bird peck: A small hole or patch of distorted grain resulting from birds pecking through the growing cells in the tree. In shape bird peck usually resembles a carpet tack with the point toward the bark, and it is usually accompanied by discoloration extending for a considerable distance along the grain and to a much lesser extent across the grain.

Birdseye: Small localized areas in wood with the fibers indented and otherwise contorted to form few too many small circular or elliptical figures remotely resembling birds' eyes on the tangential surface. Common in sugar maple and used for decorative purposes, rare in other hardwood species.

Bow: The distortion in a board that deviates from flatness lengthwise but not across its faces.

Boxed heart: The term used when the pith falls entirely within the four faces of a piece of wood anywhere in its length. Also called boxed pith.

Brashness: A condition that causes some pieces of wood to be relatively low in shock resistance for the species and, when broken in bending, to fail abruptly without splintering at comparatively small deflections.

Burl: (1) A hard, woody outgrowth on a tree, more or less rounded in form, usually resulting from the entwined growth of a cluster of adventitious buds. Such burls are the source of the highly figured burl veneers used for purely ornamental purposes. (2) In wood or veneer, a localized severe distortion of the grain generally rounded in outline, usually resulting from overgrowth of dead branch stubs, varying from 1/2 inch to several inches in diameter; frequently includes one or more clusters of several small contiguous conical protuberances, each usually having a core or pith but no appreciable amount of end grain surrounding it.

Cambium: The one-cell-thick layer of tissue between the bark and wood that repeatedly subdivides to form new wood and bark cells.

Casehardening: A stressed condition in a board or timber characterized by compression in the outer layers accompanied by tension in the center or core, the result of too severe drying conditions.

Cell: A general term for the minute units of weed structure, including wood fibers, vessel segments, and other elements of diverse structure and function.

Cellulose: The carbohydrate that is the principal constituent of wood and forms the framework of the wood cells.

Check: A lengthwise separation of the wood that usually extends across the rings of annual growth and commonly results from stresses set up in wood during seasoning.

Close grain: (See Grain)

Coarse grain: (See Grain)

Collapse: The flattening of single cells or rows of cells in heartwood during the drying or pressure treatment of wood, characterized by a caved-in or corrugated appearance.

Compression failure: Deformation of the wood fibers resulting from excessive compression along the grain either in direct end compression or in bending. It may develop in standing trees due to bending by wind or snow or to internal longitudinal stresses developed in growth, or it may result from stresses imposed after the tree is cut. In surfaced lumber compression failures appear as fine wrinkles across the face of the piece.

Compression set: Permanent compression of a group of wood fibers resulting from restraint fromswelling while taking on moisture or compressive stresses on the wetter core of wood during drying imposed by adjoining fibers or an external mechanical agency.

Compression Wood: Abnormal wood formed on the lower side of branches and inclined trunks of softwood trees. Compression wood is identified by its relatively wide annual rings, usually eccentric, relatively large amount of summerwood, sometimes more than 50 per cent of the width of the annual rings in which it occurs, and its lack of demarcation between springwood and summerwood in the same annual rings. Compression wood shrinks excessively lengthwise, as compared with normal wood.

Crook: A distortion of a board in which there is a deviation edgewise from a straight line from end to end of the board.

Cross break: A separation of the wood cells across the grain. Such breaks may be due to internal strains resulting from unequal longitudinal shrinkage or to external forces.

Cup: A distortion of a board in which there is a deviation flatwise from a straight line across the width of the board.

Density: The weight of a body per unit volume. When expressed in the c.g.s. (centimeter-gram-second) system, it is numerically equal to the specific gravity of the same substance.

Density rules: Rules for estimating the density of wood based on percentage of summerwood and rate of growth. The rules at present apply only to southern yellow pine and Douglas fir and differ slightly.

Diagonal grain: (See Grain)

Diffuse-porous wood: Certain hardwoods in which the pores tend to be uniform in size and distribution throughout each annual ring or to decrease in size slightly and gradually toward the outer border of the ring.

Dry-bulb temperature: Temperature of air as indicated by a standard thermometer.

Durability: A general term for permanence or resistance to deterioration. Frequently used to refer to the degree of resistance of a species of wood to attack by wood-destroying fungi under conditions that favor such attack. In this connection the term "decay resistance" is more specific.

Empty-cell process: Any process for impregnating wood with preservatives or chemicals in which air, imprisoned in the wood under pressure, expands when pressure is released to drive out part of the injected preservative or chemical. The distinguishing characteristic of the empty-cell process is that no vacuum is drawn before applying the preservative. The aim is to obtain good preservative distribution in the wood and leave the cell cavities only partially filled.

Equilibrium moisture content: The moisture content at which wood neither gains nor loses moisture when surrounded by air at a given relative humidity and temperature.

Extractives: Substances in wood, not an integral part of the cellular structure, that can be removed by solution in hot or cold water, ether, benzene, or other solvents that do not react chemically with wood components.

Fiber, wood: A comparatively long (one twenty-fifth or less to 1/3 inch), narrow, tapering wood cell closed at both ends.

Fiber saturation point: The stage in the drying or wetting of wood at which the cell walls are saturated and the cell cavities are free from water. It is usually taken as approximately 30 per cent moisture content, based on weight when oven-dry.

Figure: The pattern produced in a wood surface by annual growth rings, rays, knots, deviations from regular grain such as interlocked and wavy grain, and irregular coloration.

Fireproofing: Making wood resistant to fire. Wood cannot be treated chemically so that it will not char or decompose at temperatures of about 280° F. and higher. What effective fireproofing does is to make wood difficult to ignite, keep it from supporting its own combustion, and delay the spread of flame over the wood surface.

Fire-retardant chemical: A chemical or preparation of chemicals used to reduce flammability or to retard spread of fire.

Flat grain: (See grain)

Full-cell process: Any process for impregnating wood with preservatives or chemicals in which a vacuum is drawn to remove air from the wood before admitting the preservative. This favors heavy absorption and retention of preservative in the treated portions.

Gelatinous fibers: Abnormal fibers in certain hardwoods. They are associated with "Tension wood." which see.

Grain: The direction, size, arrangement, appearance, or quality of the fibers in wood or lumber. To have a specific meaning the term must be qualified.

Close-grained-wood: Wood with narrow, inconspicuous annual rings. The term is sometimes used to designate wood having small and closely spaced pores, but in this sense the term "fine textured" is more often used.

Coarse-grained wood: Wood with wide conspicuous annual rings in which there is considerable difference between springwood and summerwood. The term is sometimes used to designate wood with large pores, such as oak, ash, chestnut, and walnut, but in this sense the term "coarse textured" is more often used.

Cross-grained wood: Wood in which the fibers deviate from a line parallel to the sides of the piece. Cross grain may be either diagonal or spiral grain or a combination of the two.

Curly-grained wood: Wood in which the fibers are distorted so that they have a curled appearance, as in "birdseye" wood. The areas showing curly grain may vary up to several inches in diameter.

Diagonal-grained wood: Wood in which the annual rings are at an angle with the axis of a piece as a result of sawing at an angle with the bark of the tree or log. A form of cross grain.

Edged-grained lumber: Lumber that has been sawed so that the wide surfaces extend approximately at right angles to the annual growth rings. Lumber is considered edge-grained when the rings form an angle of 45^o to 90^o with the wide surface of the piece.

Flat-grained lumber: Lumber that has been sawed in a plane approximately perpendicular to a radius of the log. Lumber is considered flat grained when the annual growth rings make an angle of less than 45^o with the surface of the piece.

Interlocked-grained wood: Wood in which the fibers are inclined in one direction in a number of rings of annual growth, then gradually reverse and are inclined in an opposite direction in succeeding growth rings, then reverse again.

Open-grained wood: Common classification of painters for woods with large pores, such as oak, ash, chestnut, and walnut. Also known as "coarse-textured."

Plainsawed lumber: Another term for flat-grained lumber.

Quartersawed lumber: Another term for edge-grained lumber.

Spiral-grained wood: Wood in which the fibers take a spiral course about the trunk of a tree instead of the normal vertical course. The spiral may extend in a right-handed or left-handed direction around the tree trunk. Spiral grain is a form of cross grain.

Straight-grained wood: Wood in which the fibers run parallel to the axis of a piece.

Vertical-grained lumber: Another term for edge-grained lumber.

Wavy-grained wood: Wood in which the fibers collectively take the form of waves or undulations.

Green: Freshly sawed lumber, or lumber that has received no intentional drying; unseasoned. The term does not apply to lumber that may have become completely wet through waterlogging.

Growth ring: (See Annual growth ring)

Hardwoods: Generally one of the botanical groups of trees that have broad leaves in contrast to the conifers or softwoods. The term has no reference to the actual hardness of the wood.

Heartwood: The wood extending from the pith to the sapwood, the cells of which no longer participate in the life processes of the tree. Heartwood may be infiltrated with gums, resins, and other materials that usually make it darker and more decay resistant than sapwood.

Hemicellulose: A celluloselike material in wood that is easily decomposable, as by dilute acid, yielding several different simple sugars.

Honeycombing: Check, often not visible at the surface, that occur in the interior of a piece of wood, usually along the wood rays.

Impreg: Wood in which the cell walls have been impregnated with synthetic resin so as to reduce materially its swelling and shrinking. Impreg is not compressed.

Insulation, thermal: Materials that retard the transfer of heat when placed between two heat-conducting materials.

Kiln: A heated changer for drying lumber, veneer, and other wood products.

Compartment kiln: A dry kiln in which the total charge of lumber is dried as a single unit. It is designed so that, at any given time, the temperature and relative humidity are uniform throughout the kiln. The temperature is increased as drying progresses and the relative humidity is adjusted to the needs of the lumber.

Progressive kiln: A dry kiln in which the total charge of lumber is not dried as a single unit but as several units, such as in kiln-truckloads, that more progressively through the kiln. The kiln is designed so that the temperature is lower and the relative humidity higher at the entering end than at the discharge end.

Knot: That portion of a branch or limb which has been surrounded by subsequent growth of the wood or the trunk or other portion of the tree. As a knot appears on the sawed surface it is merely a section of the entire knot, its shape depending upon the direction of the cut.

Late wood: (See Summerwood)

Lignin: The second most abundant constituent of wood, located principally in the middle lamella, which is the thin cementing layer between the wood cells. The chemical structure of lignin has not been definitely determined.

Modified wood: Wood processed to impart properties quite different from those of the original wood by means of chemical treatment, compression, or treatment with or without heat.

Moisture content of wood: The amount of water contained in the wood, usually expressed as a percentage of the weight of the oven-dry wood.

Moisture gradient: A condition of graduated moisture content between successive thickness zones of wood that may be losing or absorbing moisture. During seasoning the graduations are between the relatively dry surface zones and the wet zones at the center of the piece.

Old growth: Timber in or from a mature naturally established forest. When the trees have grown during most if not all of their individual lives in active competition with their companions for sunlight and moisture, this timber is usually straight and relatively free of knots.

Oven-dry Wood: Wood dried to constant weight in an oven or above the temperature of boiling water (usually 101° to 105° C. or 240° to 221° F.).

Parenchyma: Short cells having simple pits and functioning primarily in the metabolism and storage of plant food materials. They remain alive longer than the tracheids, fibers,and vessel segments, sometimes for many years. Two kinds of parenchyma cells are recognized, those in vertical strands, known more specifically as wood parenchyma, and those in horizontal series in the rays, known as ray parenchyma.

Pit: A relatively unthickened portion of a cell wall where a thin membrane may permit liquids to pass from one cell to another. A "bordered" pit has an overhanging rim that is not present in a "simple" pit.

Pith: The small, soft core occurring in the structural center of a tree trunk, branch, twig, or log.

Plainsawed: (See Grain)

Plasticizing wood: Softening wood by hot water, steam, or chemical treatment to increase its moldability.

Porous woods: Another name for hardwoods, which frequently have vessels or pores large enough to be seen readily with magnification.

Postformed plywood: (See Plywood)

Preservative: Any substance, that for a reasonable length of time, is effective in preventing the development and action of wood-rotting fungi, borers of various kinds, and harmful insects that deteriorate wood.

Radial: Coincident with a radius from the axis of the tree or log to the circumference. A radial section is a lengthwise section in a plane that passes through the center line of the tree trunk.

Rays, wood: Strips of cells extending radially within a tree and varying in height from a few cells in some species to 4 or more inches in oak. The rays serve primarily to store food and transport it horizontally in the tree.

Relative humidity: Ratio of the amount of water vapor present in the air to that which the air would hold at saturation of the same temperature. It is usually considered on the basis of the weight of the vapor but, for accuracy, should be considered on the basis of vapor pressure.

Resin passage (or duct): Intercellular passages that contain and transmit resinous materials. On a cut surface, they are usually inconspicuous. They may extend vertically parallel to the axis of the tree or at right angles to the axis and parallel to the rays.

Ring-porous woods: A group of hardwoods in which the pores are comparatively large at the beginning of each annual ring, and decrease in size more or less abruptly toward the outer portion of the ring, thus forming a distinct inner zone of pores, known as the springwood, and an outer zone with smaller pores, known as the summerwood.

Sap: All the fluids in a tree, special secretions and excretions, such as oleoresin, excepted.

Sapwood: The living wood of pale color near the outside of the log. Under most conditions the sapwood is more susceptible to decay than heartwood.

Seasoning: Removing moisture from green wood in order to improve its serviceability.

Air-dried: Dried by exposure to air, usually in a yard, without artificial heat.

Kiln-dried: Dried in a kiln with the use of artificial heat.

Second-growth: Timber that hasgrown after the removal, whether by cutting, fire, wind, or other agency, of all or a large part of the previous stand.

Shear: Slipping of one part of a piece of wood upon another along the grain.

Softwoods: Generally, one of the botanical groups of trees that in most cases have needlelike or scalelike leaves; the conifers; also the wood produced by such trees. The term has no reference to the actual hardness of the wood.

Specific gravity: The ratio of the weight of a body to the weight of an equal volume of water at 4° C. or other specified temperature.

Spike knot: (See knot)

Spiral grain: (See grain)

Split: A lengthwise separation of the wood, due to the tearing apart of the wood cells.

Springwood: The portion of the annual growth ring that is formed during the early part of the season's growth. It is usually less dense and weaker mechanically than summerwood.

Strength: The term in its broader sense embraces collectively all the properties of wood that enable it to resist different forces or loads. In its more restricted sense, strength may apply to any one of the mechanical properties, in which event the name of the property under consideration should be stated, thus: strength in compression parallel to grain, strength in bending, hardness, and so on.

Stress: Force per unit of area.

Basic stress: The working stress for material free from strength-reducing features, such as knots, check, and cross grain. It has in it all the factors appropriate to the nature of structural timber and the conditions under which it is used except those that are accounted for in the strength ratio.

Straight grain: (Grain)

Summerwood: The portion of the annual growth ring that is formed after the springwood formation has ceased. It is usually denser and stronger mechanically than springwood.

Tangential: Strictly, coincident with a tangent at the circumference of a tree or log, or parallel to such a tangent. In practice, however, it often means roughly coincident with the growth-ring. A tangential section is a longitudinal section through a tree or limb perpendicular to a radius. Flat-grained lumber is sawed tangentially.

Tension set: A condition of wood in which a group of fibers, owing to restraint imposed by adjoining fibers or by an external mechanical agency, are fixed or set in a condition of tension as a result of a restraint on normal shrinkage during a drop in moisture content.

Tension wood: An abnormal form of wood found in leaning trees of some hardwood species and characterized by the presence of gelatinous fibers and excessive longitudinal shrinkage. Tension wood fibers hold together tenaciously, so that sawed surfaces usually have projecting fibers and planed surfaces often are torn or have raised grain. Tension wood may cause warping.

Texture: A term often used interchangeably with grain. Sometimes used to combine the concepts of density and degree of contrast between springwood and summerwood.

Tracheid: The elongated cells that constitute the greater part of the structure of the softwoods (frequently referred to as fibers). Also present in some hardwoods.

Twist: A distortion caused by the turning or winding of the edges of a board so that the four corners of any face are no longer in the same place.

Tyloses: Masses of parenchyma cells appearing somewhat like froth in the pores of some hardwoods, notably the white oak and black locust. Tyloses are formed by the extension of the cell wall of the living cells surrounding vessels of hardwood or sometimes in a similar manner by the extension of the cell wall into resinpassage, cavities in the case of softwoods.

Vessels: Wood cells of comparatively large diameter that have open ends and are set one above the other so as to form continuous tubes. The openings of the vessels on the surface of a piece of wood are usually referred to as pores.

Wet-bulb temperature: The temperature indicated by the wet-bulb thermometer of a psychrometer (which see). Theoretically, the wet-bulb temperature is the temperature at which the atmosphere would become saturated by evaporation of water without loss or gain in total heat content of the air and vapor.

Wood substance: The solid material of which wood is composed. It usually refers to the extractive-free solid substance of which the cell walls are composed, but this is not always true. There is no wide variation in chemical composition or specific gravity between the wood substance of various species, the characteristic differences of species being largely due to differences in infiltrated materials and variations in relative amounts of cell walls and cell cavities.

Workability: The degree of ease and smoothness of cut obtainable with hand or machine tools.

Xylem: The portion of the tree trunk, branches, and roots that lies between the pith and the cambium.

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